NIVOC *at your service*

LOOKING BACK . . .
and forward

THE time of year has once more come and gone, when under different conditions we should have had the pleasure of meeting our many friends at the Annual Meeting and Exhibition of the Science Masters' Association.

Personally, we miss these Exhibitions. We used to enjoy them. We believe too that they were of considerable value to both sides—to you as teachers and users of scientific apparatus, and also to ourselves as designers and suppliers ; and at the present moment many readers may be looking back, with us, to that last Meeting at Cambridge in January 1939, and at the same time forward . . . to the next Meeting.

However, we do not propose to fall into the error of Bunyan's Mr. Facing-both-ways. The achievements of the future must be built on the experiences of the past and the present. At those exhibitions it used to be our privilege to introduce ' in the flesh ' the new items of apparatus which we had brought out since the previous Meeting. We used to give a good deal of thought during the year to this side of our work. Now, however, our activities are being taken up in other directions and design and manufacture of new teaching apparatus has for the time to give way.

But we are not forgetting. When at last the S.M.A. meets again in January 194– we shall be there, all being well, more than ever at your service, with apparatus which we are confident will reveal the accumulated experience of these interval years.
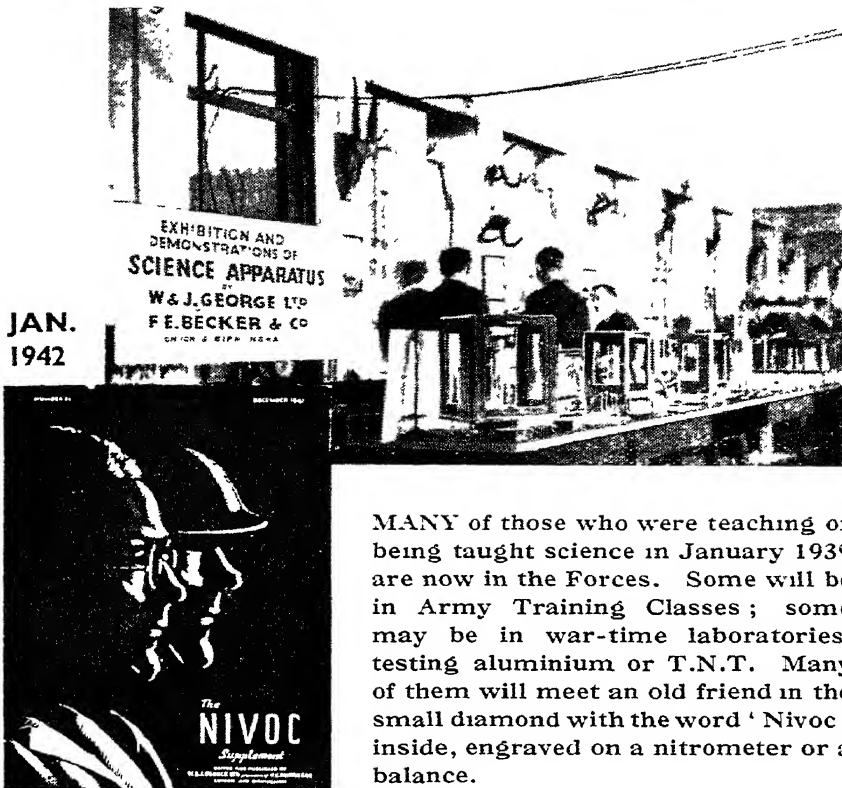
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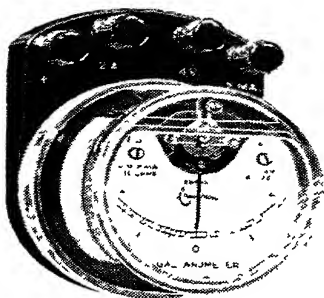
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Obviously, knowing the State's requirements, you are not expecting too much from us during this period. So while hostilities last, we ask for your indulgence and the saving up of your instrument requirements until we are again at peace. While some of your treasured instruments may have been done to death by careless usage during the war, others will have become obsolete and you will be able to start a new period with better instruments.

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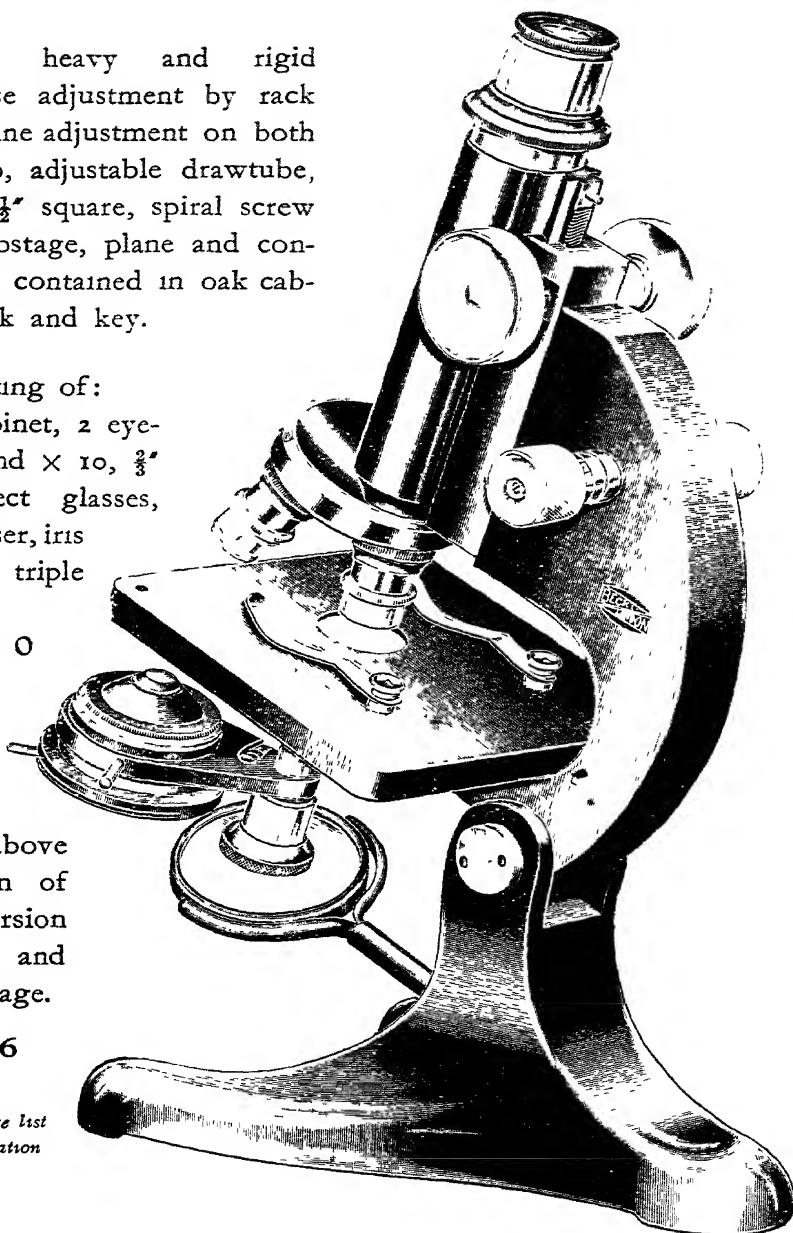
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> 39 cards 1″ long, representing monovalent radicals.
> 36 ,, 2″ ,, ,, divalent ,,
> 10 ,, 3″ ,, ,, trivalent ,,
> 1 ,, 4″ ,, ,, tetravalent ,,

The 86 cards are contained in a specially designed box.

It should be noted that the cards bear at the top right hand corner the weights of the atom or atoms concerned and from this information the molecular weights of compounds built up by the use of the cards can readily be found. The method of procedure is clearly set out in the following instructions —

INSTRUCTIONS

BASIC ions are coloured BLUE ; ACIDIC ions are coloured RED. The vertical height of each card is proportional to the VALENCY. The valency of each ion is represented by the number of dots (positive ions) and the number of dashes (negative ions) at the top right hand corner of the symbol.

Example—To find the formula for ferric sulphate :— On consulting the adjacent list, ferric iron is seen to be trivalent, and the appropriate card will be found in the second compartment of the box. The sulphate ion is seen to be divalent and its card will be found in the lower section of the third compartment. Remove the appropriate cards from their sections and place them alongside each other (blue on left, red on right). A correct formula is only obtained when the blue and red cards make a complete rectangle. By trial it will be found that this can only be accomplished in the example chosen, by taking two blue (ferric) cards and three red (sulphate) cards (See diagram.)

The required formula is :—$Fe_2(SO_4)_3$. The molecular weight can be readily calculated from the numbers appearing at the top right hand corner thus :—

$$56+56+96+96+96=400.$$

BASIC RADICALS	VALENCY
Aluminium	3
Ammonium	
Barium	
Calcium	
Chromium	
Copper (Cupric)	
,, (Cuprous)	
Hydrogen	
Iron (Ferrous)	
,, (Ferric)	
Lead	
Magnesium	
Manganese (Manganous	
,, (Manganic)	
Mercury (Mercurous)	
,, (Mercuric)	
Potassium	
Silver	
Sodium	
Tin (Stannous)	
,, (Stannic)	
Zinc	

ACIDIC RADICALS

Bicarbonate
Bisulphate
Bromide
Carbonate
Chloride
Hydroxide
Iodide
Nitrate
Manganate
Oxide
Permanganate
Phosphate
Sulphate
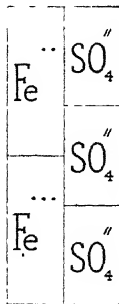
It is believed that this device, of which the copyright is registered by Brady & Martin Ltd., will prove a very helpful aid in teaching the principles of valency, and it will be seen that the formulæ of most of the salts encountered by the School Certificate candidate can be built up by the cards provided in this outfit.

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The S.M.A. Book List, which had become out of date, was suspended in 1938, and steps were taken to compile a new one. This new list was published in January, 1940. It is an 88-page booklet of the same size as the SCHOOL SCIENCE REVIEW, bound in limp cloth, containing over 900 entries, each one individually recommended as suitable.

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REVIEW

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EDITED BY

G. H. J. ADLAM, O.B.E., M.A., B.Sc.

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ARTICLES between 2,000 and 4,500 words in length are most convenient. Subjects requiring more generous treatment may be arranged as two consecutive articles, each in itself complete up to a point.

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The ring formulae of Organic Chemistry are to be treated as diagrams.

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PRACTICAL CHEMISTRY IN DIFFICULT TIMES

By G H LOCKET
Harrow School

THERE had been a good deal of speculation, for some years before the war, on the extent to which " micro " methods and, also, simplified and makeshift apparatus should be encouraged, considering that most schools were then adequately provided But, although organic chemistry has received a good deal of attention in this respect, largely no doubt on account of the importance of the micro-technique in organic chemistry generally (see, incidentally, an article by R. J Kerr-Muir, *S.S.R.*, XXII, **87** (1941), 268), much less has been heard about the possibilities as regards elementary work in inorganic chemistry. It was hoped that a discussion might be held and demonstrations made, but such a meeting would not be representative, or indeed possible, at present. However, since the matter now takes on a new importance, it seems worth while to begin to consider some possibilities.

Incidentally, it is obvious that here is an opportunity for recapturing a source of interest and drive, which in recent years has been disappearing from chemistry teaching. Simplified apparatus and the makeshift type of experiment can have very real educational value, and it seems by no means fantastic to suggest that, by designing apparatus from " salvage " and showing that with such things there is little that cannot be done, ingenuity of the right kind can be stimulated, which will be of lasting and, perhaps, incalculable value. One need only instance the development of micro-technique in organic analysis, with its astounding achievements, from the work of Pregl during and after the last war. Even if there is not time for each boy to make his own apparatus, the possibilities of fresh design can be shown. The extent to which this aspect of the question is followed up must depend largely on the nature of the requirements demanded of the school training ; in some schools, it has always been prominent, quite apart from the present situation.

There is also the urgent question of economy and of carrying on in

difficult or well nigh desperate conditions. But this aspect of the matter is so obvious that there is no need to enlarge upon it.

In order to make clear the points so far mentioned, a selection of actual examples will now be given.[1] They do not go beyond the requirements of, roughly, the School Certificate stage, and some are selected as rather extreme examples.

It will probably be best to consider them under two headings. First, the production of makeshift apparatus, either to meet a real emergency, such as hurried evacuation to quarters not fitted up, or for the use of isolated workers wanting to carry out experiments at home. Secondly, there are the modifications of procedure necessitated by shortage of material.[2] Finally, an index of those Chemistry Notes from the *S.S.R* which appear relevant is appended.

EXAMPLES OF MAKESHIFT APPARATUS

(1) *The Balance.*   Contrary to what is generally supposed, a balance weighing to 0·01 gm. is quite easy to make. Mine cost 8*d.* (pre-war) and was constructed in about an hour as follows. A cantilever beam was made from $\frac{1}{5}$th-in. glass rod (see Fig. 1). The knife-edges are parts of safety-razor blades fixed in position with a cement made by adding plaster of Paris to melted resin until a paste is obtained. The pointer, a glass rod drawn out, is fixed with the central knife-edge and carries a piece of pressure tubing, which slides up and down to adjust sensitivity. A card attached to the stand carries a graduated scale. The stirrups are of drawn-out rod and from these hang wire hooks, to which pans (watch-glasses) are suspended by threads fixed on with the same cement. The central knife-edge rests on a support of $\frac{1}{4}$-in. glass rod, which is carried by a wooden stand, the pans resting on corks when not in use. The sensitivity is actually greater than 0·01 gm. with 15–20-gm. load. The balance was made to show to some boys who wanted one for work at home ; it has been used for quantitative

---

[1] No particular claim for originality is made, although each one has been thought out independently, and all have been used at one time or another in actual teaching (in one case, the preparation of oxygen, to show some boys what could be done about it in a home laboratory)

[2] In this connection there arises the extreme case of the use of drop reactions on slides. While this method is very valuable in its place (see N. F Newbury, *The Teaching of Chemistry*, 1934, p. 118), it is best dealt with, in my opinion, as a special subject and, in the early stages of training at all events, has obvious drawbacks for teaching purposes It will therefore not be dealt with here.

determinations and found to work well, though of course it could be improved upon greatly with a little skill. A more robust design in aluminium sheet is described by R. D. East (*S.S.R.*, XVIII, **69** (1936), 132).
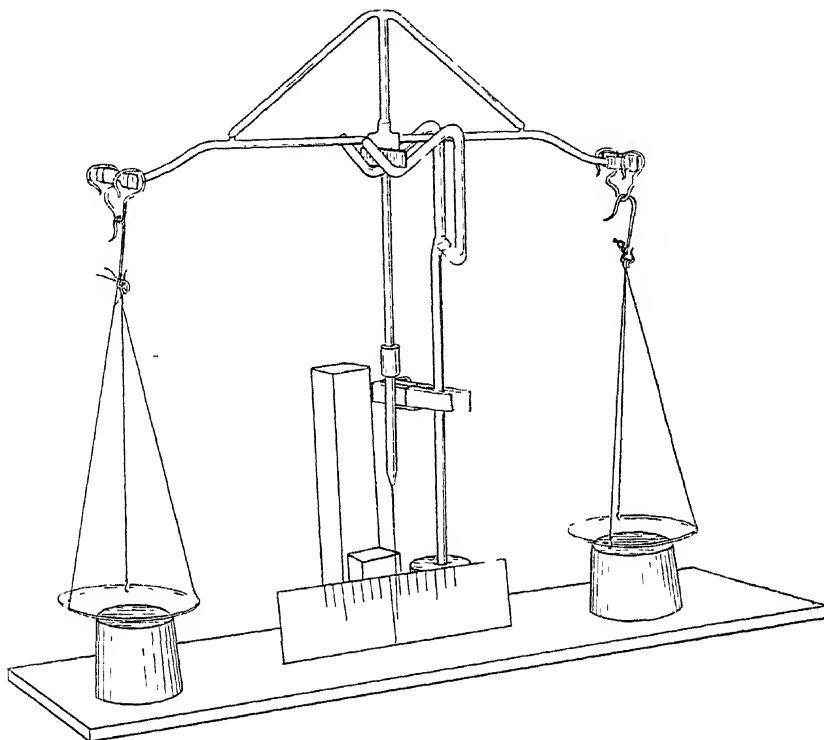
FIG 1.

(2) *Emergency Methods of Heating.*—The laboratory furnishers have been showing some excellent burners of the alcohol, paraffin and petrol-vapour type, which are almost complete substitutes for gas, except (as far as I know) for use with a blow-pipe. Wick stoves are quite good for evaporating, distilling water, etc. If " micro " methods are in use a small flame, such as that produced by a spirit lamp, is adequate, and even a candle-flame is quite hot enough for many purposes. I recently found a boy sealing off a piece of glass tubing with a candle flame, using a mouth blow-pipe. If the blow-pipe is supported on a block at the right height, both hands are left free and the method is surprisingly efficient. An obvious development from this is the use of a wick lamp and blow-pipe as used by Post Office linesmen   For a furnace, to illustrate lime-burning, for instance, or

for firing clay, a coke stove made from an old bucket is usually adequate, or, if a heating-furnace is employed in the building, much may be done with that.

An inverted tin, with holes pierced in the bottom, for use in heating, is so satisfactory that I have taken to using it, entirely on its own merits, for evaporating. With such a shield, only a tiny flame is needed, and substitute burners, e.g., a small paraffin lamp or candle, or even melted wax in a tin with a string wick, could always be used in an emergency, and they all work perfectly well.

(3) *Crucibles*. It is quite surprising what crucibles made from London clay will stand up to. I have not tried them for quantitative work, but if dried slowly and well fired they are most useful and their making provides some valuable lessons.

(4) *Evaporating Basins*. My colleague, Mr. W. H. Barrett, has shown that very serviceable glass basins can be made from burnt-out electric light bulbs. A small flame is first directed near the base of the bulb, whereupon a hole is blown inwards as the glass softens. A mark is then made round the widest part of the bulb with a glass-cutter or file and a crack made with an electrically heated nichrome wire. Ordinary cracking with a hot bead is often successful, but not always. Beaker-flasks can be made by cracking off higher up. The central glass support for the filament will always fuse on these vessels to form a handle.

Retort Stands would be difficult to replace, but supports made by attaching spring American clothes-pegs to suitable wooden uprights have certain merits and have found many uses (e.g., to carry a micro-retort). The fixed position of the clamp is often an advantage.

Volumetric Apparatus, particularly burettes of the rubber pinch-cock type, are easily made from glass tubing and calibrated against existing burettes or by weight. Scales can be drawn in indian ink and attached with a suitable paper varnish.

EXAMPLES OF SMALL-SCALE EXPERIMENTS AND PREPARATIONS

(1) *The Preparation of a Gas (Oxygen)*. The simplification is extreme in this example, which is chosen purposely to show what can be done with a minimum of supplies. A piece of scrap tubing was sealed at one end and charged with two potassium chlorate tablets (such as are sold for sore throats), powdered and mixed with a little manganese dioxide. This tube was joined to a delivery tube through

a bored cork (glue will make a poor quality cork air-tight).   On heating
with a candle-flame, six test-tubes full of oxygen were obtained (collected
over water).   Deflagrating spoons were made by hammering the ends
of short pieces of thick iron wire and inserting these into corks.   The
elements sulphur, phosphorus, carbon and magnesium were burnt in
the gas and the reactions of their oxides with litmus shown.   The other
tubes were used for showing the ignition of a glowing splint and the
effect of carbon dioxide on lime-water.   The examination of the
properties of gases on a small scale is almost always easy, and an
excellent arrangement for collecting over water has been described by
F. W. Hunt (*S.S.R.*, XIX, **76** (1938), 592).   For the preparation of
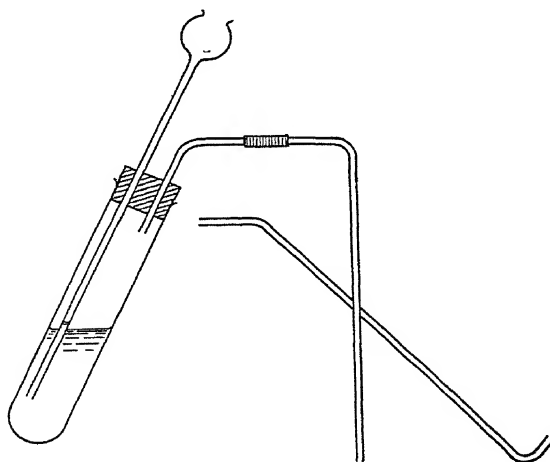
FIG 2.

gases by individual boys we have recently made the apparatus in Fig. 2
standard ; it can be used in most cases with immense saving of material.

(2) *The Preparation of Salts*, either by neutralization or by the
action of acids on oxides, are, of course, easily carried out in test-tubes.
This applies particularly to ferrous sulphate, where oxidation is
prevented.

(3) *Quantitative Work* is always important and the standard methods
lend themselves to all sorts of modifications.   To take one simple
example—the estimation of the weight of carbon dioxide evolved by
the action of acid on a carbonate.   I usually employ the following
method, entirely on its own merits.   The experiment is carried out
easily in a forty-minute period, leaving time for the calculations.   A
boiling-tube suspended with a wire and a quarter filled with acid is

weighed, together with a small tube, which is filled with the carbonate and the whole weighed again, thus giving the weight of the carbonate. The small tube is now dropped into the acid which, when all action is over, is raised *just* to boiling.   The tube is then cooled under the tap and weighed again.   The results obtained by boys are as good as those which they get by any other method weighing to 0·01 gm.
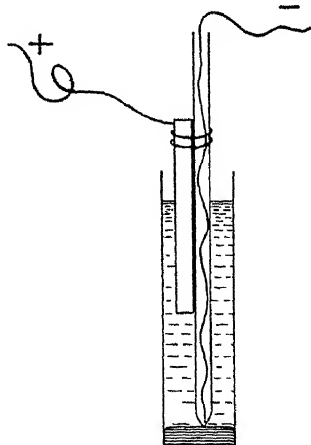
(4) *Demonstration of a Technical Process* (Alkali and Chlorine Manufacture).   Take a small (" No. 8 ") disused dry cell and pull out the carbon.   Seal a piece of copper wire into a piece of glass tubing, drawn out at one end, with some of the pitch from the top of the cell.   Bind the carbon to the glass tube with another wire, at the same time making contact between this wire and the carbon. The cell is a $1\frac{1}{2}$ in. $\times \frac{3}{8}$-in. specimen-tube, at the bottom of which is a globule of mercury forming the cathode, while the electrolyte is saturated brine (Fig. 3).   Four volts from a battery are sufficient for electrolysis, during which chlorine can be smelled and made to bleach litmus paper.   After 5–10 minutes the brine can be washed out with clean water, whereupon hydrogen in minute bubbles is seen to stream from the mercury amalgam, while the water becomes alkaline and " feels soapy."

FIG. 3
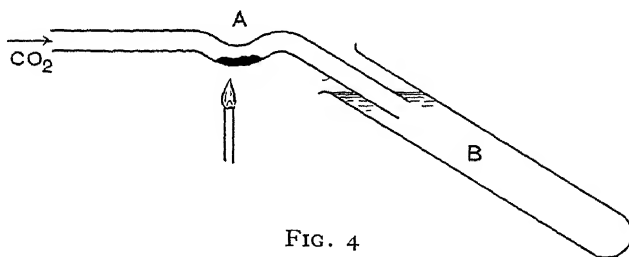
FIG. 4

(5) *To Show the Adsorptive Power of Charcoal.*   Take six matchsticks and heat them in a tin or covered crucible to dull redness until fumes stop coming off.   Cool and powder.   Put a *very small* crystal of lead nitrate into a narrow dry test-tube and heat to fill the tube with nitrogen dioxide.   Cover the mouth of the tube with the thumb or cork up, and cool.   Add the powdered charcoal and shake up.   The colour is discharged.

(6) *Allotropy (the two forms of Phosphorus).* As a source of red phosphorus, two dozen safety match-boxes will suffice. The striking surfaces are cut off and warmed in water, acidified with a little hydrochloric acid. The wood and paper are fished out and the residue washed by decantation and then transferred to a filter and dried. The powder (red phosphorus, antimony sulphide and powdered glass) is now placed in a tube as shown (Fig. 4). Carbon dioxide is passed in slowly and the water in B is kept hot. The mixture is now heated and the phosphorus vapour is condensed to the yellow variety which collects under the water in brownish beads. It is left with chromic acid over-night, when a white wax-like bead is left which is easily sucked into a tube, drawn out to a capillary, with water and preserved.
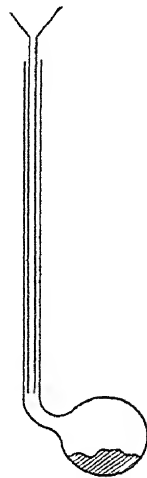
FIG. 5

(7) *Preparation of Phosphorus Trichloride* By passing chlorine over a little yellow phosphorus in the same type of tube and fitting a suitable receiver, phosphorus trichloride is easily made (*S.S.R.*, XIX, 75 (1938), 447).

(8) *Preparation of Nitric Acid* is easily carried out on a micro scale, using a retort made by blowing a good bulb on a piece of ordinary ¼-in. tubing. The sulphuric acid is introduced with the aid of a funnel made from drawn-out tubing (Fig. 5). This apparatus is also used for purifying phosphorus trichloride

S S R. NOTES

[*S M B.*, I and II = *Science Masters' Book*, 1st and 2nd Series]

PREPARATION AND PROPERTIES OF GASES

"A New Sulphuretted Hydrogen Apparatus." A Eslick and S. V. Brown. XIV, 55 (1933), 353.

"A Home-made Kipp's Apparatus" J H H McRae and T. T. Richards. XVI, 65 (1935), 137; *S M B*, II, 131

"Automatic Gas Generator for Hydrogen, Carbon Dioxide or Hydrogen Sulphide." XVII, 68 (1936), 618

"Kipp's Apparatus" J. O Blaksley. XIX, 76 (1938), 591

"Apparatus for Storing Gases" E J Harris XVI, 63 (1935), 410

"Note on the Use of Milk Bottles as Gas Jars." R. Hitchcock. XVI, 63 (1935), 414

"Class Experiments on the Determination of Carbon Monoxide and Acetylene in Coal Gas" A. E. Bell XVIII, 70 (1936), 285.

"A Device to Enable an Ordinary Burette to be used for Simple Gas Analysis." G. Fowles VI, 21 (1924), 51; *S.M.B*, I, 35.

" Simple Apparatus for Gas Analysis." XIX, **76** (1938), 594.
" Relative Density of Carbon Dioxide and Hydrogen by Direct Weighing—a Demonstration." W. V. Lloyd. XXI, **84** (1940), 1145.

COMPOSITION OF WATER AND ELECTROLYSIS

" Combustion of Hydrogen." R. G. Reid XVI, **65** (1935), 139.
" Action of Magnesium on Steam." J. D. Peterkin. XV, **60** (1934), 524.
" Action of Magnesium on Steam " T. A Muir. XVIII, **70** (1936), 283.
" Simple Apparatus for Burning Magnesium in Steam." E. A. Taylor. XXI, **84** (1940), 1143.
" Apparatus for Class-work in Electrolysis—School Certificate Standard." F. W. Hunt. XII, **48** (1931), 396 ; *S M B.*, I, 22.
" Electrolysis." H. C. Palmer XVI, **65** (1935), 141 ; *S M.B.*, II, 174.
" Polarity of Mains." H. C. Palmer. *S.M B.*, II, 244

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" Magnetic Rectifier." C. P Varnam V, **18** (1923), 103.
" Chemical Rectifiers " G N Pingriff *S M B*, II, 175.
" Chemical Rectifier for Electrolysis " W. B. Barker XIV, **55** (1933), 359
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WILL-O'-THE-WISP

By ROBERT E. D. CLARK, M A., Ph D
Bournemouth School

THOUGH at one time in the centre of scientific interest and discussion, will-o'-the-wisps, or as they used to be called *ignis fatui* (silly lights), are now but a memory of the past. So much is this the case that it is possible to look up the subject in literally dozens of reference works published during the past thirty years without eliciting a single fragment of information Their memory is, however, just kept alive by folklorists and by a few text-books on chemistry which, for some unknown reason, please to connect them with the spontaneously inflammable but impure phosphine obtained by the action of caustic soda on phosphorus.

The reason for this virtual disappearance of will-o'-the-wisps from current thought is chiefly due, no doubt, to two causes. First and foremost, there is the draining of the land ; traditionally, will-o'-the-wisps appeared as a rare phenomenon in those trackless and extensive bogs which for the most part disappeared during the nineteenth century. There are scores of records of their appearance in boggy localities which are now dry fields and meadows. Secondly, the appearance of a mysterious light in a field no longer occasions the interest which it once evoked. The story is told that some years ago inexplicable lights were often seen in a mountainous region in Canada and that a scientific expedition set out to solve the mystery. The lights proved to be genuine enough—they were caused by the headlamps of motor-cars as they passed a short but steep gradient on a distant road ! After such experiences, it is no wonder if current interest in will-o'-the-wisps has declined. Yet perhaps it is not too much to hope that it will revive once more during the black-outs of the present war !

BEFORE THE NINETEENTH CENTURY

The early history of will-o'-the-wisps is wrapt in obscurity. A fond imagination might see them depicted in the fire-god Gibil of ancient Babylonia, who is described as being " fire of the reeds with

pure and brilliant flame." In the Middle Ages they were connected with superstitions—often of the crudest kind—many of which have been preserved by the folklorists (see Jackson, Brand, etc.). We read, for instance, that the priests once took advantage of the mysterious flames by telling the people that they consisted of souls who had escaped, for a brief space, from Purgatory " to move the people to pray for their entire deliverance, by which they gulled them out of much money to say Mass for them, every one thinking that it might be the Soul of his or her deceased Relations." According to another opinion, the lights were the souls of unbaptized babies—though it is not very clear why these should have been luminous !

Amongst the first of the scientists to interest themselves in the matter was Sir Isaac Newton. Newton believed that the lights were due to luminous vapours. Together with other examples, he cited them as evidence that light was caused by the commotion of bodies. It mattered not, he urged, *how* such commotion was caused, " whether by Heat, or Friction or Percussion or Putrefaction or vital Motion," light could always be produced as, for instance, by " Sea-water in a raging Storm ; quick Silver agitated in vacuuo , the Back of a Cat, or Neck of a Horse, obliquely struck or rubbed in a dark place, Wood, Flesh and Fish while they putrefy, Vapours arising from putrefied Waters usually called *Ignis Fatui*," etc. He then adds : " The *Ignis Fatuus* is a Vapour shining without heat, and is there not the same difference betwen this Vapour and Flame, as betwen rotton Wood shining without heat and burning Coals of Fire ? " As we shall see, Newton's view of will-o'-the-wisps may account for some though not all instances of the phenomenon.

In the following century, the opinion soon spread that the lights were simply due to luminous insects. William Derham (1731), however, convinced himself that this was not always the case. He has left us with a most entertaining account of how he got near to one of the lights and examined it for himself. " Seeing one," he says, " in a calm dark Night, with gentle Approaches I got up by Degrees within two or three yards of it, and viewed it with all the care I possibly could. I found it frisking about a dead Thistle growing in the Field, until a small portion of the Air (even such as was caused by the Approximation of my self) made it skip to another Place, and thence to another and another." The light appeared like a " fired vapour " and did not consist of a large number of smaller lights such as would have been caused by a group of luminous insects.

Derham then proceeds to give a translation of an account of will-o'-the-wisps in Italy, written in 1728 by the Italian scientist G. B. Beccari

According to this, a friend of Beccari was walking along a road one dark night when one of these mysterious lights appeared in front and travelled with him for more than a mile. It actually threw more light upon the road than the torch which had been brought as a light. This, however, was no isolated event. Beccari discovered that similar lights had been seen again and again in Italy, throughout all the seasons of the year. He describes them as " breaking sometimes to all Appearances into two, and a very little while after meeting again into one Body, sometimes fleeting like waves, and letting drop some parts like Sparks out of a Fire." In the mountains it was related that lights no larger than the size of a candle were to be seen, but, in the plains, they often appeared of much larger dimensions, and the peasants ascribed them to birds " the Belly and other parts of which," remarks Derham, " are resplendent like our shining Flies."

A well-known case of *ignis fatuus* was seen by Thomas Shaw in a bog in Palestine. " In travelling by Night through the Valleys of Mount Ephraim," he writes, " we were attended for above the Space of an Hour, with an *ignis fatuus*, that displayed itself in a Variety of extraordinary Appearances. For it was sometimes globular or like the Flame of a Candle ; immediately after it would spread itself, and involve our whole Company in its pale inoffensive Light ; then at once contract itself and suddenly disappear. But in less than a Minute it would again exert itself as at other times, or else, running along from one place to another, with a swift progressive Motion, would expand itself, at certain Intervals, over more than two or three Acres of the adjacent Mountains." In this case, the weather was stormy and Shaw was inclined to the view that the light was electrical in origin. In this connection, R. L. Ives has recently published an account of some of the extraordinary forms which electrical discharges may take. Sometimes trees will appear to be on fire (as in the story of Moses and the burning bush, Exodus iii. 2) or human beings will become enveloped in light without their being aware of the fact (compare Exodus xxxiv. 29).

Will-o'-the-wisps in Palestine bring to mind a most remarkable instance of a possibly similar nature which occurred in ancient times, when Julian attempted to rebuild the temple at Jerusalem in order to frustrate Christian prophecies. The Jews entered into this work with

great enthusiasm and officials pressed it on with zeal. But, according to Marcellinus, himself a pagan and a friend of Julian, " formidable globes of fire arose from the foundations ; they frequently exploded over the workmen, wounding many of them. Sometimes they made the ground unapproachable. Finally this conquering fire, continuing to hurl itself with fierceness upon the workmen as if resolved to disperse them, compelled them to abandon the undertaking " (see Warburton).

Another description of the *ignis fatui* comes from Peter von Musschenbrok (1744). " Now they dilate themselves," he writes, " and now contract. Now they go on like waves and rain as it were sparks of fire, but they burn nothing. . . . Some that have been catched were observed to consist of a shining viscous and gelatinous matter, like the spawn of frogs, not hot or burning but only shining," [1] and he adds that " it is a mere fiction that such fires are evil spirits, or wandering ghosts, misleading travellers out of mere spite, to plunge them into ditches and bogs, as some trifling Philosophers have told us."

From these and other accounts it is clear that what was known as the *ignis fatuus* in the seventeenth century really covered a number of distinct phenomena. Only in the following century was any real attempt made to distinguish between the true will-o'-the-wisp and other kinds of light such as luminous insects and birds or electrical discharges.

NINETEENTH CENTURY

From beginning to end, the nineteenth century was a century of controversy so far as will-o'-the-wisps were concerned. Various obvious explanations of lights which appeared at night had been put forward, and it seemed to many that there could now be no reason to postulate a wholly different kind of light which could appear as a flame on marshy ground. In short, will-o'-the-wisps served to divide those scientists who will accept no fact—however good the human testimony in its favour—unless they can also find an explanation, from those who believe that factual truth is in no way dependent upon whether an explanation [2] is immediately available.

[1] Often called *meteoric mucilage* after the peasants' belief that it consisted of meteors which had hit the ground ! (Phipson)

[2] An objective study of the past history of science seems to indicate that the latter party have proved correct far more often than the former (Clark, 1940).

Taken as they stand, the accounts of first-hand witnesses of will-o'-the-wisps could scarcely be better. Professor Bessel (1838) described how he had seen numerous little flames spring from water-logged soil during a dark drizzling night. The flames were non-luminous and resembled burning hydrogen. According to another account (published by J. G. Galle, 1851) the phenomenon was once common outside Dresden. Here one student saw a flame an inch in length appear and disappear a number of times about three inches above the muddy bottom of a ditch. It burned for a brief moment and then went out, returning repeatedly after about three-second intervals. No odour was noticeable.

One of the most detailed accounts came from Professor Knorr, a German professor of physics. He tells us that he saw will-o'-the-wisps three times during his life, though the first two occasions were during his childhood. On the third occasion he was a student at Berlin, where he had been studying mathematics and science for two years. He was near a small country village in Germany in August 1825. Three bridges passed over boggy land, and while Knorr was passing over the third of them he was surprised to see some lights near the edge of a forest near by. At first he thought that perhaps the peasants were bringing in the cattle, but although there was still light enough to see whether people were walking about in the meadows, he could see no one. He attempted to go towards one of the lights which was nearer than the others, but it proved too dangerous owing to the treacherous nature of the bog. Disheartened, he started to go on his way when a light suddenly appeared in an accessible position. At the side of the road ahead was an embankment on which tall grass was growing, followed by rushes, and between the stalks of the rushes he could see that one of the lights was shining out.

" Bushes, rushes and grass were lit up so brightly by the light that for some time I gazed at the lovely picture entranced," writes Knorr. But soon he proceeded to investigate. He advanced as far as he was able but after he could feel no bottom to the marsh with his short stick, he lay down flat and tried to remove the reeds in front of him so as to get as good a view of the light as possible. In the end, the will-o'-the-wisp was only about eight inches out of reach, but Knorr was not able to see its extreme bottom owing to part of a rush which he had been unable to beat away. The visible portion of the light appeared as a flame about five inches in height, and between an inch and a quarter and an inch and a half in breadth. Its shape

was cylindrical. In the centre the colour was yellow, but towards the sides and top it appeared bright violet and then disappeared against the dark background without showing a sharp outline

The air was motionless at the time and the flame burned steadily. It moved backwards and forwards a little when Knorr took out his handkerchief and waved it vigorously in order to make a draught, but he thought it moved much less than a normal flame would have done. When he took his stick and passed it rapidly right through the flame there was also a little quivering.

The end of Knorr's stick was covered with a little piece of brass and he held this in the will-o'-the-wisp for quarter of an hour, but it was not warmed to the slightest degree, showing that there was no flame in the ordinary sense of the word. Knorr stirred the mud near the light but this also had no effect, showing that bubbles of gas arising from the bottom of the marsh could hardly have been the cause Moreover, there seems to have been no noticeable odour either in this case or with any other will-o'-the-wisps which have been seen by others. After trying everything possible, Knorr was finally obliged to leave the light. He was unable to return to the spot the next day.

Many other instances have been collected by Müller and by Fornaschon, both of whom cite many remarkable appearances of the light. Fornaschon had himself seen a will-o'-the-wisp. The following are a few of the more interesting examples.

On a dark night in 1842, a cabman lost his way. Ahead a sparkling light appeared " looking like the appearance of steel when it is beaten by a blacksmith " The party moved towards it to ask the way. But the sparks then turned into flames which stood poised in the air— their lower parts about a foot above the level of the ground. They were visible for several seconds and rose into the air without noise. The ground beneath was wet but not marshy.

In May, soon after 1850, a remarkable case of will-o'-the-wisps was seen by Brackenhoff in Oldenburg. With a guide and four companions he was passing one night over a moor, a part of which was used for getting peat. There had been a violent storm and the guide lost his way in the pitch darkness, the party being astray for two hours. Suddenly some lights were seen in the distance. Then, shortly afterwards, about a dozen lights appeared in their immediate neighbourhood. They looked like candle flames poised in the air with their tops moving about. One member of the party caught a

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flame in his hand, but it at once disappeared. There was no noise, nor smell, nor apparently heat noticed in connection with the flames. Later on the party saw St. Elmo's fire on the ends of their umbrellas but were able to recognize no resemblance between the two kinds of light.

A remarkable case was also recorded by C. W. Schultze, who went for a trip in a boat on September 2nd, 1882, when he was thirty-five years of age. There had been much flooding of the surrounding country and the night was intensely dark. All of a sudden little flames appeared in the air a few inches above the level of the water. They looked like burning matches except that they were larger in size and not so luminous. For some time the boat was able to guide itself by their light and so avoid striking the flooded banks. Each flame lasted for about fifteen seconds and then went out. They only appeared at distances from one another of about two to four boat-lengths—though we are not told the length of the boat. After a heavy shower the lights appeared no more. Schultze goes on to say that he could not possibly have been drunk on this occasion as he had only been drinking soda water and that in moderation ! Meyer believes that both Schultze and Brackenhoff were thoroughly reliable observers.

A few years ago (1937) the writer was informed by Herr Wisnewski of Bonn that he had seen will-o'-the-wisps near Hanover thirty years previously. Two flames suddenly appeared in the darkness and then disappeared after a few seconds. Later, another flame followed them. There was much rotting vegetation in the vicinity but the flames, which were several inches in height, resembled burning petroleum. The air had a pungent odour of carnations at the time.

From many of these accounts it appears as if spontaneously inflammable or highly luminous gas could be formed at times as a result of bacterial decomposition of the organic matter found in swamps. But, although marsh gas is commonly formed and comes to the surface when many a muddy pool is stirred with a stick, it has never been observed to catch fire of its own accord.

It appears, however, that there is at least one record of what was evidently a spontaneously inflammable gas being formed in nature. According to Dressler there was once upon a time a pond near a marshy wood near Löwenburg in Silesia. In the adjoining wood will-o'-the-wisps were frequently seen. The pond itself was a cemetery for superfluous cats and dogs, while the local butchers added the skins

of animals. In the summer time masses of organic matter the size of a hand could be seen floating about which had evidently been blown up by gases formed as a result of putrefactive changes. On an exceedingly hot afternoon, when the sun was shining brightly on the water, Dressler noticed that when one of these air bladders exploded it ignited with a yellowish blue flame. At first he thought he was deceived but, after repeatedly observing the phenomenon, he decided that combustion was indeed taking place. The same thing was observed during several subsequent summers and on one occasion no less than five of these bladders caught fire at the same time. Finally, the lake was drained and nothing of the kind was ever seen again.

Such are a few accounts of the mysterious will-o'-the-wisp and it is difficult to believe that they are baseless. The fact that no certain explanation of such luminescence or combustion is yet available has little to do with its reality. It is not logically possible to adopt the attitude of a writer to *The Times* (November 1st, 1862) who, after outlining every extant theory of will-o'-the-wisps and showing that one and all were unsatisfactory, concludes : " I boldly denounce this vagabond as a rank impostor, and I challenge the production of evidence in proof of his existence, either past or present . . . he never presents himself except to a drunken man in boggy ground on a foggy night." (This letter was, of course, followed by several interesting letters in which the writers assured the public that *they* at all events had not been drunk when they saw the phenomenon !)

EXPLANATIONS

Explanations of will-o'-the-wisps have been as numerous as they are unsatisfactory. Volta suggested that bubbles of marsh gas might be fired electrically : " I fire inflammable air by the simple electric spark," he wrote to Priestley in great excitement, " even when the electricity is very moderate, which explains the formation of the *ignis fatui*, provided they consist of inflammable air issuing from marshy ground, by the help of the electricity of fogs, and of falling stars, which are very probably thought to have electrical origin."

According to another view will-o'-the-wisps were caused by the mysterious *auswittering* (see S.S.R., October, 1937, p. 48), which was supposed to exude from mineral veins. The chemist Glauber thought that the appearance of a bluish lambent flame on the ground afforded indisputable evidence of the presence of mineral veins.

The discovery of spontaneously inflammable phosphine was, of course, hailed as the long-sought-for explanation. But the absence of the characteristic odour of this substance seems to afford a strong objection to this view.

Müller suggests that perhaps the light may be due to an unknown *Irrlichtbacillus*.[1] Just possibly this view is correct, though one cannot help being reminded of Herr von Bodelschwingh's theory, according to which epilepsy was caused by an infection of *Bacillus infernalis* in the blood—a small organism which possessed two horns and a tail, though apparently no cloven hoof !

Another point which may or may not have something to do with will-o'-the-wisps is the fact that when a match is brought near certain plants (e.g. *Dictamnus albus*) on a hot still summer's day, they sometimes give a small puff of flame due, it would seem, to the evolution of an inflammable gas.

Not only the appearance of the light itself, but the *wandering* of the light has occasioned further explanations. The writer of the article *Irrlicht* in *Der Grosse Brockhaus* suggests that the wandering is due to the physiology of the human eye. At a distance the light is very faint and so it disappears like the stars when it is looked at directly. It is stated that this has given rise to the idea that the light moves about.

Another explanation is put forward in a popular scientific work by E. C. Brewer. In order to explain the alleged fact that the light disappeared when approached and follows behind instead, Brewer says : " When we run towards an *ignis fatuus* we produce a current of air, which drives the light forwards. When we run away from the *ignis fatuus*, we produce a current in the way we run, which attracts the light inflammable gas in the same course." A nice explanation indeed !

CONCLUSION

So troublesome Willie has not yet given up his secret ! It is, however, worth making a suggestion as to how he makes his light.

Many recent biochemical investigations have shown that volatile organo-metallic compounds are easily formed by the action of anaerobic bacteria, and it is well known that such compounds are often spontaneously inflammable. Now many of the traditional places for the appearances of will-o'-the-wisps seem to be those where mineral ores

[1] *Irrlicht* = will-o'-the-wisp (German).

occur (e.g. Silicia, Bologna, etc.), so that Glauber's generalization (see above) may not be without foundation.

If the will-o'-the-wisps were caused by some particular organo-metallic compound which, mixed with methane, caused bubbles of the latter to ignite spontaneously, the extreme rarity and localized character of the phenomenon would find a ready explanation

It should not be difficult for the Science Society of a favourably situated school to carry out a simple investigation on the matter. Small quantities of compounds of a large variety of elements (say, mixed with plaster of Paris) could be placed in marked positions in a pond or bog where methane is normally generated, and after stirring with a stick at night it could be observed whether luminous or spontaneously inflammable vapours were ever evolved. The present writer had hoped to start such an experiment at Gordonstoun School, Elgin, Morayshire, but plans were upset by evacuation.

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ON SOME POPULAR SUPERSTITIONS OF THE CHEMISTRY TEXT-BOOKS

By J. C. SPEAKMAN
Sheffield University

In dealing with undergraduates fresh from the schools and in marking examination scripts written by candidates still at school, I am continually meeting certain misinterpretations of the facts of Chemistry. They continue to arise because they persist in a majority of the text-books (otherwise excellent) upon which the scholar and his teachers are inevitably largely dependent for their material. Needless to say, in marking papers, allowance is made for the fact that it is the usual sources of information that are at fault, and not the candidates. But for that very reason I feel the more impelled to draw attention to three of these superstitions which seem especially serious.

(1) *Electrode Reactions during Electrolysis*. When an aqueous solution of sodium sulphate (let us say) is electrolysed between inert electrodes, the facts are that hydrogen (not sodium) appears at the cathode, and oxygen (not free sulphate) at the anode. Moreover, closer examination shows that the solution near the cathode (provided it is not stirred) becomes alkaline, and the solution near the anode acid by an equivalent amount. The traditional interpretation of these facts was as follows : that sodium ions were discharged at the cathode, producing neutral (metallic) sodium atoms (primary process), and that the sodium then reacted with water to produce sodium hydroxide and hydrogen (secondary process)—i.e.

$$Na^+ + \textcircled{e} \rightarrow Na \; ; \; Na + H_2O \rightarrow NaOH + \tfrac{1}{2}H_2 \uparrow \; ;$$
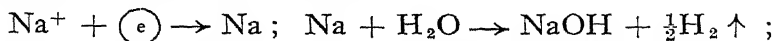
and similarly that sulphate ions were discharged at the anode, giving neutral sulphate radicals (primary process), which then reacted to give sulphuric acid and oxygen (secondary process)—i.e.

$$\tfrac{1}{2}SO_4^= \rightarrow \tfrac{1}{2}SO_4 + \textcircled{e} \; ; \; \tfrac{1}{2}SO_4 + \tfrac{1}{2}H_2O \rightarrow \tfrac{1}{2}H_2SO_4 + \tfrac{1}{4}O_2 \uparrow .$$
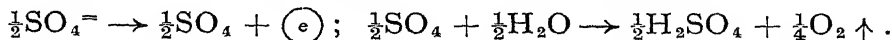
This explanation (which dates back for at least a century) would not now be accepted by any electrochemist. And, considered in

terms of the ionic theory, it is at once seen to be absurd. The sodium in a sodium sulphate solution exists wholly, or almost wholly, as sodium ions ; the same is true of the sodium in a caustic soda solution. These sodium ions are exactly the same whether they are accompanied by sulphate or by hydroxide ions. Therefore, what we are asked to believe is that the ions are first discharged at the cathode, and immediately, and in the same situation, undergo the reverse change ; and similarly that the sulphate ions, after being neutralized at the anode, change their minds and resume the *status quo*. As has been pointed out (for instance by Glasstone, this journal, 1935, **63**, 336), the true explanation certainly is that, under the conditions operative here, sodium ions are never discharged at all, because there is present in solution another kind of ion which, in spite of its lower concentration, can be discharged by the cathode far more easily—viz. the so-called hydrogen ion [1] ; and again that sulphate ions are not discharged, because discharge of hydroxide ions takes place preferentially at the anode.

This may be put into a more precise form by reference to the deposition potentials involved. Broadly speaking, a cation may be discharged when the potential of the cathode with respect to the solution (π) becomes more negative than the value given by the Nernst equation :

$$\pi = \pi_0 + \frac{RT}{nF} \log_e \{\text{activity of ion}\}.$$

π_0 is the standard electrode potential characteristic of the particular species in question, n is the valency of the ion, and the logarithmic term becomes $\frac{0\cdot06}{n} \log_{10}\{\text{activity of ion}\}$ when R and F are given their appropriate values and the temperature, T, is taken to be about room-temperature. At the anode an anion may be discharged when the potential becomes more positive than the value given by the equation $\pi = \pi_0 - \frac{0\cdot06}{n} \log_{10}\{\text{activity of ion}\}$. Complicating effects may arise through overvoltage and polarization ; but, although these are sometimes important, they do not affect the present argument. For sodium the constant π_0 is about $-2\cdot7$ volts on the hydrogen scale, and from a normal solution of a sodium salt (in which the activity will not differ greatly from unity) sodium ions will not discharge until

[1] The hydrogen ion is certainly hydrated in solution, and is more properly referred to as the hydronium or oxonium ion, $[H_3O]^+$.

the potential of the cathode becomes more than 2·7 volts below that of the solution.[1]   For hydrogen the constant π_0 is by definition zero, and, since in a neutral solution the hydrogen-ion activity is about 10^{-7}, the potential for hydrogen discharge is approximately given by

$$\pi = 0 + \frac{0\cdot06}{1} \log_{10}\{10^{-7}\} = -0\cdot4 \text{ volt.}$$ This value is much less negative than that for sodium discharge, and this is still true even when we make allowance for the solutions becoming more alkaline near the cathode and for overvoltage effects ; therefore, discharge of hydrogen ions will take preference over discharge of sodium ions. The sodium ions *carry* the current towards the cathode, but it is hydrogen ions (derived from the solvent) that are actually *discharged* there.   As a result sodium and hydroxide ions accumulate around the cathode—i.e., caustic soda is formed.   A similar quantitative consideration would show that discharge of hydroxide ions takes preference over discharge of sulphate ions.   The sulphate ions carry the current towards the anode, but it is hydroxide ions that are discharged there, with the consequent formation of sulphuric acid.

A somewhat different case is exemplified when the anode is of metallic copper, which on electrolysis goes into solution as copper ions.   The usual, and incorrect, interpretation would be that the discharged sulphate radicals convert the copper to copper sulphate, which then dissolves.   The true interpretation is that direct anodic dissolution of copper ($Cu \rightarrow Cu^{++} + 2\text{(e)}$) takes preference over any other electrode process.

(2) *Degree of Dissociation of Strong Electrolytes.*   For weak electrolytes (such as acetic acid or ammonium hydroxide) the conductance ratio (Λ/Λ_0) approximately equals the degree of ionic dissociation in solution.   But for strong electrolytes the degrees of dissociation thus arrived at (e.g. 84% in N/10 sodium chloride) are certainly wholly incorrect.   The close agreement often found between the degrees of dissociation based on the conductance ratio and those based on the Van 't Hoff factor, i, (an agreement which rightly impressed physical chemists in the early days of the Arrhenius theory) makes a good story ; but it is now known to be incidental.   Neither value is correct   Most strong electrolytes are almost completely dissociated, at any rate up to quite high concentrations.   The fact that the conductance-ratio

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[1] This holds for the deposition of *pure* sodium ; when the cathode consists of a very dilute sodium amalgam (as in the Castner-Kellner process), deposition occurs at a much less negative potential ; π_0 is in effect altered.

may be less than 100% and the Van 't Hoff factor correspondingly less than the value expected for complete dissociation is due to general interionic attraction, and not to the formation of " undissociated molecules." It may well be difficult to decide just how much of the (admittedly rather difficult) modern theory of strong electrolytes (cf. Glasstone's *Electrochemistry of Solutions*, or Chapter IX of his *Recent Advances in Physical Chemistry*, 1937 edition) can be presented in a school; but that is surely no adequate justification for teaching what is generally recognized to be untrue, and has subsequently to be unlearnt by the pupil.

(3) *Types of Valency*. In elementary expositions of the electronic theory of valency it is often stated that *three* types of valency have to be postulated: (*a*) electrovalency or polar valency, as in sodium chloride, (*b*) covalency, as in ethane or carbon tetrachloride, and (*c*) co-ordinate or semi-polar bonds, as in $BF_3.NH_3$ or the sulphoxides. This is very misleading. Essentially there are only *two* types,[1] (*a*) and (*b*). (*c*) is at the best no more than a special case of (*b*), with a difference in the mode of origin of the bond (and therefore of its properties) which it is *occasionally* justifiable to stress, but not always. Indeed, the attempt to make too sharp a discrimination between (*b*) and (*c*) easily leads into a dangerous position.

For instance, sulphuric acid in the un-ionized form may be represented by the electronic formula I, or more simply by II,[2] where the

[1] A detailed subdivision of the two main types of valency, due to Pauling, has been recently summarized by Copley (this journal, March 1941)

The further question, whether electrovalency and covalency represent essentially different modes of combination, or whether they are ideally pure types representing the two ends of a series within which all actual bonds occupy intermediate positions (i e part electrovalent, part covalent) is of great interest, but must not detain us here. Sidgwick in his books on valency inclined towards the former view   G N. Lewis and Pauling support the latter, which is coming to be generally accepted now.

[2] This is the usual electronic formulation of the sulphuric acid molecule It is now realised that it may not represent the whole story ; the S—O bonds appear to possess partial double bond character, and the same applies to other similar oxyacids, their ions, and treated compounds (*e g cf* Sutton, *Annual Reports Chem. Soc*, 1940, 74). But this does not affect the point which is being made in the present article,

lines stand for a pair of shared electrons (i.e. a covalency bond). In this formula the bonds between H and O and between hydroxyl O and S are ordinary normal covalencies. Those between S and the other two (non-hydroxylic) O-atoms are formally semi-polar bonds, and if we wish we can legitimately stress the fact by formulæ such as III or

$$\begin{matrix} H{-}O \\ \\ H{-}O \end{matrix}\!\!>\!\!S\!\!<\!\!\begin{matrix} O \\ \\ O \end{matrix} \qquad (III) \qquad\qquad \begin{matrix} H{-}O \\ \\ H{-}O \end{matrix}\!\!>\!\!\overset{\oplus}{S}\!\!<\!\!\begin{matrix} \overset{\ominus}{O} \\ \\ O_{\ominus} \end{matrix} \qquad (IV)$$
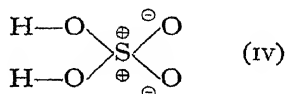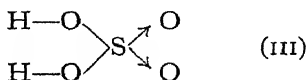
IV. But it is not essential to use these special formulations; complete information regarding the situation of the electrons is implied by a formula such as I or II.

(The above statements regarding the S—O bonds can be confirmed by inspection of I or II, involving a comparison of the number of electrons possessed by each atom in the compound (a shared pair counting as one electron for each of the two atoms thus bonded) with the number occurring in the original, neutral atom. Thus, confining our attention to the outermost shell only, the two O atoms on the right had each originally 6 electrons, and now have in effect 7 (6 unshared $+\ \frac{1}{2}$ of 2 shared), so that each atom bears a negative "*formal charge*" of 1; whilst the S atom, which also originally possessed 6 electrons, now has effective possession of 4 ($4 \times \frac{1}{2}$ of 2), so that its formal charge is $+\ 2$. The two S—O bonds in question are therefore semi-polar. Other ways of testing for polarity by reference to imaginary steps by means of which the molecule might have been built up are apt to mislead if at any stage a bond has been formed between entities not initially uncharged.)

Next let us consider the situation when the acid becomes ionised (V). All four O atoms are joined to the S by identical bonds, and it is no longer justifiable to call two bonds covalent and two semi-polar. The above procedure leads to the set of formal charges shown at VI,

$$2[H]^{+}\ \left[\begin{matrix} O \\ \\ O \end{matrix}\!\!>\!\!S\!\!<\!\!\begin{matrix} O \\ \\ O \end{matrix}\right]^{=} \qquad (V) \qquad\qquad 2[H^{+}]\ \left[\begin{matrix} \overset{\ominus}{O} \\ \\ O_{\ominus} \end{matrix}\!\!>\!\!\overset{\oplus}{S}\!\!<\!\!\begin{matrix} \overset{\ominus}{O} \\ \\ O_{\ominus} \end{matrix}\right] \qquad (VI)$$
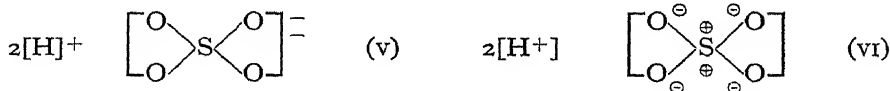
from which it appears that there are, as it were, two units of " semi-polar-bondness " to be divided equally between the four bonds. It thus becomes impossible to discriminate rigorously between normal and semi-polar bonds, or to answer " Yes " or " No " to the question

whether any particular bond is semi-polar. A somewhat similar state of affairs arises in connexion with the ammonium ion.

Summarising, therefore, all such bonds essentially belong to one type ; they are all covalency bonds. When it can fairly be regarded as having been set up between two initially neutral atoms, one of which has provided both of the pair of bonding electrons, then the covalency bond will be associated with a large electrical dipole ; and, if we wish, we can stress this fact by some special method of formulation and by calling the bond semi-polar or co-ordinate. In other circumstances it is not generally possible to make a rigid distinction between normal and semi-polar covalency bonds. In either case, the formula of the type I or V supplies by implication all the information obtainable from such simple (and, after all, conventionalized) methods of representation.

THE PHOTOGRAPHY OF SPECTRA

By W. ASHHURST, B.Sc , M.Sc.Tech.
Stretford Grammar School

THE photography of spectra is seldom tackled in the school laboratory. It has been found, however, that this experiment is full of interest as most boys possess cameras. Quite good results can be obtained using simple apparatus. It is the aim of the following account to describe the arrangements found satisfactory by the writer.

A spectroscope, used in the ordinary way, produces a spectrum as a real image which is viewed through the eyepiece. A photograph of this spectrum can be obtained by fixing a photographic plate at the place where the real image is formed. This spectrum, however, is very small. Its size can be increased by using an objective of longer focal length. It must be emphasized that the spectrum is merely enlarged, the resolution remaining the same. The resolving power (i.e. the ability to separate two very close spectral lines) depends upon the size, angle and refractive index of the prism. A longer spectrum with increased resolution may be obtained by using two prisms.

Figs. 1–5 are spectrograms taken using an ordinary school spectroscope. The collimator is adjusted as usual and the light from a metallic arc focused upon the slit. Two 60° glass prisms are used to increase the dispersion. The telescope is replaced by a double tube, in one end of which a lens is fixed. The lens is achromatic and of about 30 cm. focal length. (An achromatic lens is not essential.) The other end of the tube is covered with tracing-paper. By setting the tube so that the light from the prism passes down its axis, a spectrum is obtained on the tracing-paper. By altering the length of the double tube this spectrum is focused.

In order to take a photograph using the arrangement described, the tracing-paper is replaced by a cardboard cap in which a piece of bromide paper is wedged.

Figs. 6–10 were taken using a cheap plane grating replica in place of the prisms.

Fig. 1. Iron arc
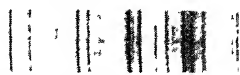
Fig. 2. Copper arc

Fig. 3. Aluminium arc

Fig. 4. Zinc arc
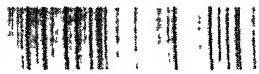
Fig. 5. Nickel arc

Fig. 6. Iron arc
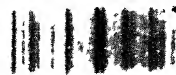
Fig. 7. Copper arc
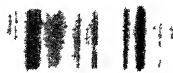
Fig. 8. Aluminium arc

Fig. 9. Zinc arc

Fig. 10. Nickel arc
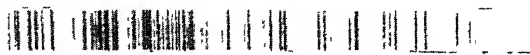
Fig. 11. Iron arc

Fig. 12. Copper arc

Fig. 13. Aluminium arc
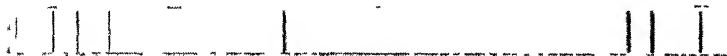
Fig. 14. Zinc arc

Fig. 15. Nickel arc

Fig. 16. Magnesium sulphate in carbon arc

The Region of the Photographs is about 3,500° A to 5,000° A.

All the spectrograms reproduced have been taken directly on bromide paper. This is convenient, for a good dark room is not necessary. Its drawback is that it cannot be used to cover the whole visible spectrum.

The following is an account of a much more satisfactory arrangement :

The Concave-Grating Spectrograph

It is now possible to obtain replicas of concave gratings. They are marketed by the Central Scientific Company, Chicago, but can be obtained through the British scientific instrument firms. They are available in a variety of rulings and focal lengths and also in two grades. The one used in the apparatus here described has 15,000 lines to the inch and a focal length of 106 cm. It is catalogued at $10.50, but is subject to a large import duty. With such a grating a variety of experimental work is possible.

There are three mountings for concave gratings in common use.

1. *The Rowland Mounting.* This is probably the most common mounting, but it takes up a lot of room. Full details of this mounting are given in most advanced text-books on optics.

2. *The Stigmatic Mounting.* In this case a parallel beam is allowed to fall obliquely upon the grating which is arranged normal to the photographic plate. Giving a stigmatic image, it is a very useful mounting for special work, e.g. the investigation of the spectral emission from different parts of a source.

3. *Eagle Mounting.* This mounting is very compact and is that used in the taking of Figs. 11–16

Details of the Mounting of the Grating

A strong box 8 in. by 9 in. and 45 in. long is made in 9-ply with a strengthened base. The inside is blackened and two panels, X and Y, are cut to provide access to the grating, G, and prism, M. A cheap adjustable slit, S, is screwed on to one side of the box as shown. The camera, PP', is attached on one end, a suitably sized slot being cut out of the end of the box. The metallic arc A, is contained in the lamp-house of a lantern and focused upon the slit by means of the condensing lens. The light from the slit falls on the totally reflecting glass prism C, and is reflected on the grating. The prism is mounted by means of sealing-wax on the end of a piece of brass rod, which fits fairly tightly in a hole in a block of wood fastened to the bottom of the box. This

mounting enables the prism to be rotated, so that the light may be made to fall centrally upon the grating. The prism is equidistant from the slit and the camera. The grating is clamped in a special mount which provides for rotating and tilting. The distance of the grating from the camera is about 106 cm. For focusing, this distance has to

X, Y   Removable panels to give access to grating and prism
G   Grating.
M   Prism.
S   Slit
PP'   Camera.
A   Arc.
C   Condensing lens.
W   Wedge.
K   Screen around prism
L   Scale.
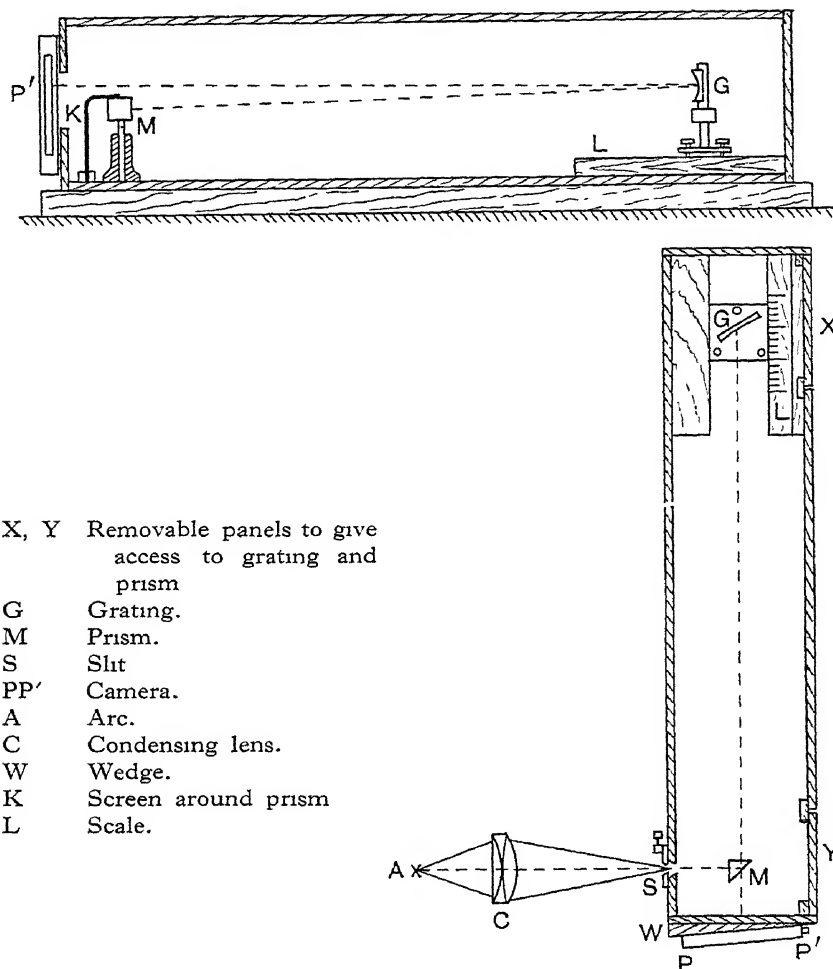
be varied, and this is accomplished by sliding the grating mount along guides fastened to the bottom of the box. The position of the grating is noted by reference to a scale, L. From the grating, the light is reflected back along the box. By slight tilting of the grating, the reflected light is made to pass just above the prism and to fall upon the camera. A blackened shield K, prevents scattered light from the

prism reaching the camera. The " camera " is the back portion of an old quarter-plate camera. It has a focusing-screen and plate-holders can be inserted in the usual way.

ADJUSTMENTS

Little time is required for adjusting the apparatus accurately enough for school use.

Using a carbon arc and a fairly wide slit, the prism is rotated so that the light falls upon the grating. This is done by removing the panel Y and twisting the brass rod supporting the prism. On looking into the box through the camera aperture, the diffracted images should be visible on the sides of the box. By adjusting the tilt of the grating, the diffracted light is made to fall on a ground-glass focusing-screen. The first order spectrum is brought upon the screen by slightly rotating the grating   The carbon arc is then replaced by an iron arc. The iron spectrum has an abundance of lines and is a convenient spectrum for focusing purposes. Using as fine a slit as is practicable, the position of the grating is altered until the spectral lines are sharp. This visual adjustment can usually be improved by taking a series of focusing photographs with the position of the grating altered by one or two millimetres each time. By this means, the best position of the grating can be found accurately. It will probably be found that not all the lines are in focus on any one photograph. By studying the series of focusing spectrograms, the amount of tilt of the plate which is necessary to bring all lines in focus can be estimated. In the apparatus described, a wedge W, about half an inch to zero is inserted between the camera and the end of the box.

This apparatus has been moved frequently and no trouble has been experienced in adjusting it anew.

It is difficult to give the exposure times as so much depends upon the slit width and arc. In this apparatus the slit is of poor quality and much better results should be possible with a better one. Exposures of about 20 seconds are used for the metallic arcs.

The apparatus when in use is clamped to a bench and vibration does not seem to have caused trouble with the short exposures used.

MEASUREMENT OF SURFACE TENSION AND DENSITY BY A MODIFIED CAPILLARY RISE METHOD

By E TYLER, D Sc , M.Sc , F.Inst.P., A M I.E.E., A F.R.Ae S

Head of the Science Department, South-East Essex Technical College, Dagenham

Introduction

THE capillary tube method of measuring the coefficient of surface tension σ of a liquid becomes more attractive if means are available for applying external pressure to the enclosed space above the meniscus.

Typical of this class of experiment is the depressed meniscus method of Ferguson and Hake. [1]

In the ordinary capillary rise method only one value of the height of the elevated liquid above its free surface is obtainable with a given tube, and substitution of such a value in the theoretical expression is essential for the evaluation of σ.

Any graphical method that might be evolved as a result of modified experimental technique is advantageous and preferable to this direct substitution method.

With this aim in view, the following modified capillary rise method has been devised : such a method possesses the following advantages :—

(*a*) Minimizes errors due to irregularities in the bore of the tube.

(*b*) Eliminates the need of cutting the tube at the section coincident with the meniscus, when measuring the diameter of the tube with a travelling microscope.

(*c*) Yields reliable results, since the method involves taking several independent observations all of which are capable of graphical representation.

(*d*) The utilization of a projection method for purposes of measurement, combined with the mercury thread method for obtaining the internal bore of the tube, eliminates the employment of

11   159

a microscope ; in addition it facilitates expeditious manipula-
tion and provides an excellent class demonstration.

(e) Method is equally effective for reduced pressures where the
liquid is drawn further up the tube by suction, thereby
increasing the range of observation.

THEORY OF METHOD

When a vertical capillary tube A is lowered into a liquid, and its
upper end is connected to a pressure gauge B and variable pressure
supply D (Fig. 1), the height to which the liquid rises in the capillary
tube depends not only upon the dimensions of the tube and nature
of the liquid but upon the difference in pressure between P, that
within the space above the meniscus c, and the external atmospheric
pressure.

Assuming the liquid wets the tube and makes zero angle of contact
with the walls of the tube, let the following notation be adopted.

h = the height of the elevated liquid in the tube above the free
surface d,

ρ = the density of the liquid under test,

σ = the coefficient of surface tension of the liquid,

h_1 = the difference in the liquid levels a and b in the gauge,

ρ_1 = the density of the gauge liquid, and

r = the radius of the capillary tube.

Since there is equality of pressure at a and d, namely, atmospheric,

$$P - \frac{2\sigma}{r} + \rho g h = P - \rho_1 g h_1$$

Whence
$$\frac{2\sigma}{r} = g(\rho h + \rho_1 h_1) \quad . \qquad . \qquad . \qquad . \quad (1)$$

Allowing for the volume of the liquid above the lower edge of the
meniscus c, the " effective elevation " is $h + \frac{1}{3}r$ (to a first approxima-
tion), so that equation (1) becomes

$$\frac{2\sigma}{r} = \rho g(h + \tfrac{1}{3}r) + \rho_1 g h_1$$

or, rewriting,

$$(h + \tfrac{1}{3}r) = \frac{2\sigma}{r\rho g} - \frac{\rho_1}{\rho}h_1 \qquad . \qquad . \qquad . \quad (2)$$

This equation is linear in $(h + \frac{1}{3}r)$ and h_1 ; thus, for a given tube,
if a series of values of h and h_1 are obtained, a plot of $(h + \frac{1}{3}r)$ as
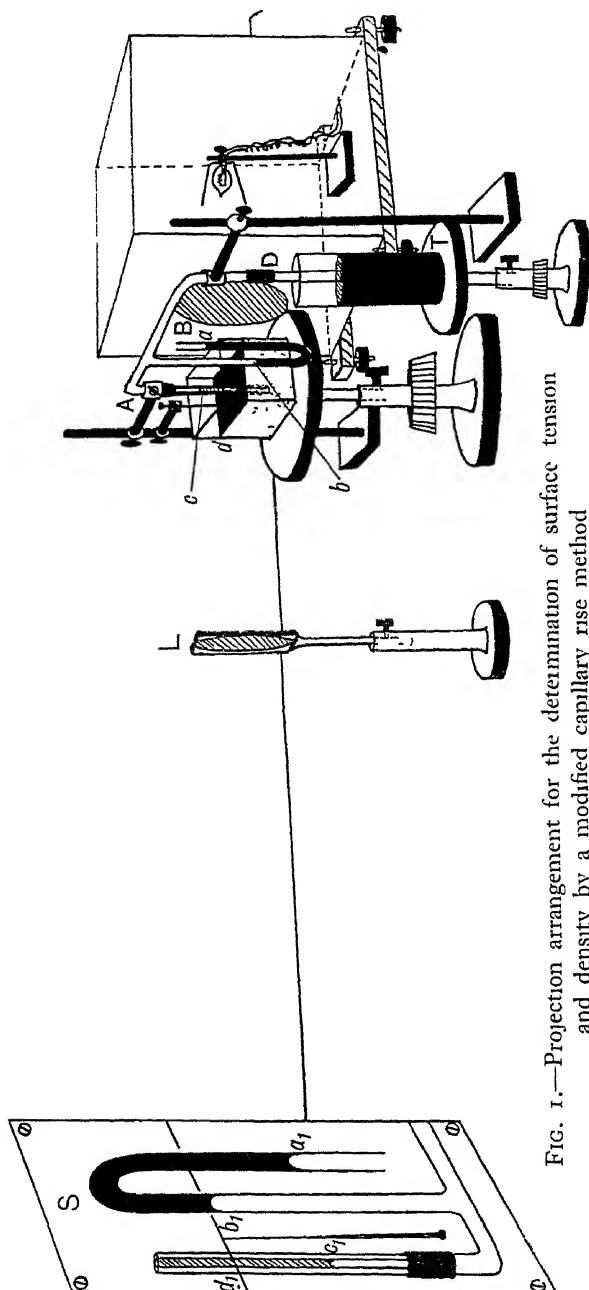
FIG. 1.—Projection arrangement for the determination of surface tension and density by a modified capillary rise method

ordinate against h_1 as abscissa gives a straight-line graph not passing through the origin (Fig. 2).

From such a graph the following information is derived :—

(a) The slope of the graph expressed as $\dfrac{OA}{OB} = \dfrac{\rho_1}{\rho}$, hence ratio of the liquid densities.

(b) The intercept OA corresponding to $h_1 = 0$ is $\dfrac{2\sigma}{\rho gr}$, whence

$$\sigma = \frac{\rho gr\ OA}{} \qquad (3)$$

(c) The intercept OB corresponding to $h + \tfrac{1}{3}r = 0$ is $\dfrac{\rho_1 gr}{2\sigma}$

giving $\sigma = \dfrac{\rho_1 gr . OB}{2} \qquad (4)$

(d) Using the same liquid in both the tube and the gauge $\rho = \rho_1$, hence, slope of the graph $= 1$, i.e., the intercepts OA and OB are equal, therefore

$$\sigma = \frac{(OA + OB).\rho gr}{4} \qquad (5)$$

(e) For tubes of different diameters but with the same liquid a family of straight-line graphs are obtained, all having the same gradient but of varying intercepts.
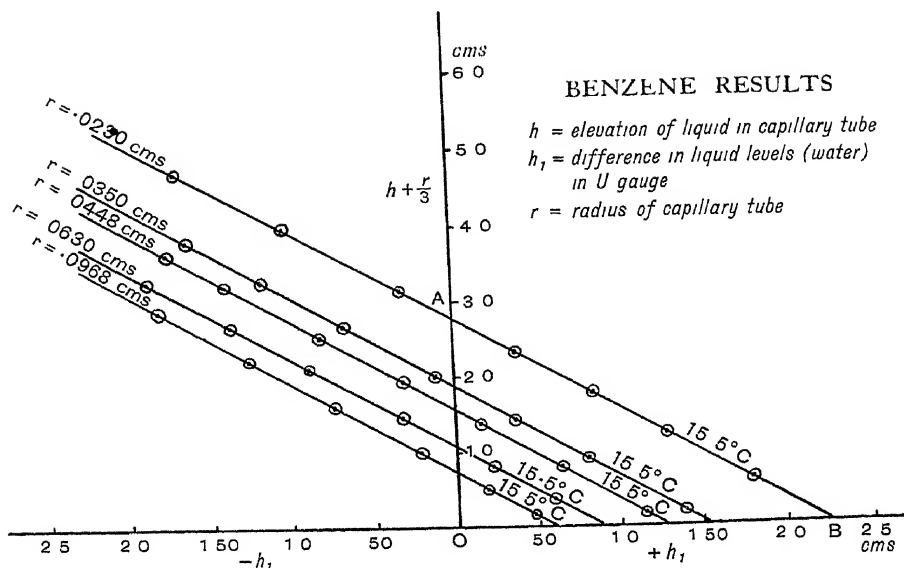
FIG. 2.

The conditions represented by equations 3, 4 and 5 may thus be used to compute σ, and $\dfrac{OA}{OB}$ to obtain $\dfrac{\rho_1}{\rho}$, or, if $\rho_1 = 1$, $\rho = \dfrac{OB}{OA}$.

Further analysis is possible if we use the series of tubes, and co-ordinate the results of the family of straight lines in Fig 2.
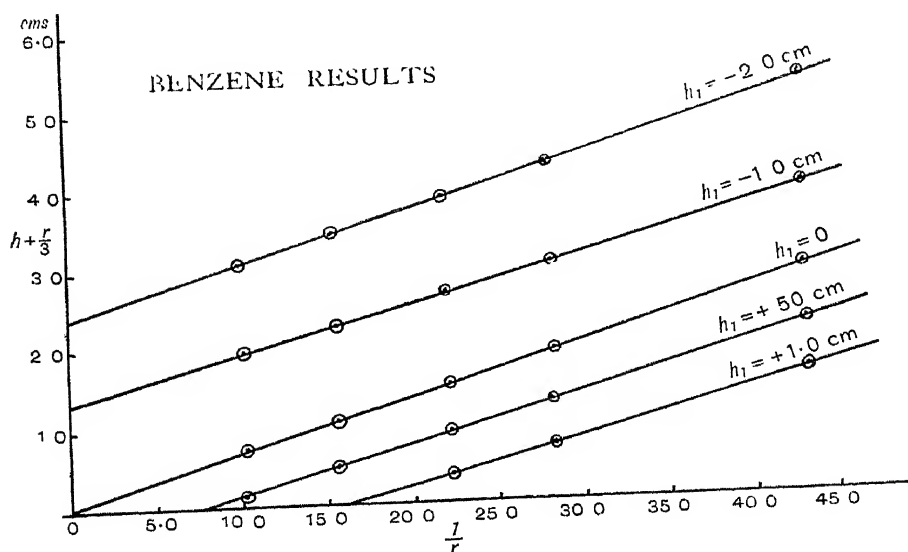
FIG. 3.

Referring to equation (2), if we regard h_1 constant for a given set of tubes, the equation is now linear between the variables $(h - \frac{1}{3}r)$ and $\frac{1}{r}$. Thus by setting up ordinates at any given value of h_1 on Fig. 2 we are able to obtain the corresponding values of $(h + \frac{1}{3}r)$ and $\frac{1}{r}$ respectively for each tube If this process is repeated for different h_1's, and the interpolated results are then plotted with $(h + \frac{1}{3}r)$ as ordinate and $\frac{1}{r}$ as the abscissa, we obtain a family of straight lines (Fig. 3) all having the same slope $\frac{2\sigma}{\rho g}$; σ is thus expressible as $\frac{\rho.g \times \text{slope of graph}}{2}$, and since the slope of the graph is now involved, a more reliable value of σ should be obtained.

EXPERIMENTAL ARRANGEMENT

The schematic arrangement and final set-up of the apparatus is shown in Fig 1

Both the capillary tube A and U gauge B are arranged vertically and as close as possible to each other, so that observation of the heights h and h_1 of the liquids in the capillary tube and the gauge can be conveniently measured, either with a travelling microscope or by means of a projection method. For reasons already stated, the latter method is adopted, employing a lantern and projection lens L, at a magnification $10 \sim 20$. Provision is made for applying excess pressure by adjusting the levelling table T and water cylinder D to any convenient setting.

Thus, in an actual test the levels a, b, c, d are all projected upon the distant screen S and their respective positions, a_1 b_1 c_1 d_1, marked. The process is repeated over as wide a range as possible, including observations for reduced pressures below atmospheric.

The position of the free surface of the liquid in the containing tank is then finally located in the usual manner with the aid of a steel needle or pin.

Calibration of all measurements made at the screen is then effected by inserting a graduated glass scale in the place previously occupied by the capillary tube and thus measuring the actual size of a known number of scale divisions, hence obtaining the magnification employed.

By this means, errors in the measurements arising from distortion caused by defects in the optical system become automatically eliminated.

Adhering to the non-use of a travelling microscope the bore of the tube is determined by the mercury thread method.

If the length of the thread approximates to 20 cm., sufficient accuracy can be obtained with the aid of a $\frac{1}{2}$-metre scale and projection lens.

With a thread less than 10 cm. we may resort to the projection method ; allowance for the " end effects " must now be made.

Regarding the ends of the mercury thread as hemispheres, the volume of mercury is $\pi r^2(l - \frac{2}{3}r)$, where l is the measured length between the extremities of the menisci, thus, equating this to its mass m and density ρ_m, a more exact value of r is derived from the relation

$$r = \frac{m}{\pi \rho_m (l - \frac{2}{3}r)},$$ where the approximate value of r obtained from $\pi r^2 \rho_m l = m$ is substituted in the $\frac{2}{3}r$ term.

SPECIMEN RESULTS

Typical results for Benzene [2] are included in Figs. 2 and 3 and Tables 1 and 2. The alignment of the graphs is clearly revealed and the values of σ and ρ display very good agreement.

Equally consistent results were obtained with water ($\sigma = 71 \cdot 1$, $\rho = 1 \cdot 00$) and chloroform ($\sigma = 32 \cdot 7$, $\rho = 1 \cdot 48$), but owing to the present economy the non-publication of these results in full has become imperative.

RESULTS FOR BENZENE

TABLE 1

INTERPOLATED DATA FROM FIG. 2

ρ = density of liquid, ρ_1 = density of gauge liquid
= 1 0 for water

Temperature °C.	Radius of Tube r cm	Intercepts		$\sigma = \frac{\rho g r \; OA}{2}$ dynes-cm $^{-1}$	$\sigma = \frac{\rho_1 g \, OB}{2}$ dynes-cm $^{-1}$	Density $\rho = \frac{\rho_1}{\text{slope}}$ gm -cm $^{-3}$
		OA	OB			
15·5	0·023(0)	2 75	2 39	26 6	27 0	0·86
15·5	0·035(0)	1 87	1·57	26 7	26 9	0 85
15 5	0 044(8)	1 52	1 29	28 4	28 3	0 85
15 3	0·063(0)	1·05	0 87	27 4(9)	26 8	0 84(7)
14·2	0 096(8)	0 72	0 60	28 9 .	28 2	0 85
				Average $\sigma = 27 5$ ρ by density bottle = 0 86(5) at 15 5° C		

TABLE 2

INTERPOLATED DATA FROM FIG 3

Difference in Gauge Levels h_1 cm	Density of Liquid ρ gm -cm.$^{-3}$	Slope of Graph	Average Slope	$\sigma = \dfrac{\rho\,g\ \text{slope}}{2}$ dynes-cm $^{-1}$
0		0 069(0)		
+ 0 50		0 062(0)		
+ 1·0	0 86	0 061(4)	0 064	27·0
− 1 0		0 061(0)		
− 2 0		0 066(6)		

In view of such consistency, the method merits a place among the list of recognized surface tension experiments and should prove useful for post-intermediate and scholarship work.

Furthermore, interesting numerical exercises can be devised, thus extending the mental effort of the student.

REFERENCES

1 *Proc Phys. Soc.*, 1929, **41**, 3.

2 For these results I am indebted to E A Duligal and H Ludlow, senior day students of the South-East Essex Technical College.

COLOUR BLINDNESS

By G. F. WOODHOUSE, M.A.
Highfield, Sedbergh, Yorks.

THE following is a brief account of some work I did a long time ago. It is now ten years since I retired and I thought that it was about time I put these results on record, mainly in the hope that many Science Masters would do some work on this interesting subject. Very little apparatus is needed, only a set of Edridge Green wools (Messrs. Curry & Paxton). The Holmgen set of wools is not so good. The only other thing is a spectroscope in which a fine vertical slit can be fitted.

There are other methods of testing, such as the lantern test, which is very good, but I never used it. The wool test may be looked upon as a preliminary, the spectroscope is the real test as it gives the key to the boy's perception. Colour blindness (a bad term ; there is no blindness as a rule ; it should be called Poor Colour Perception) is very common among men. I had some 30 or 40 cases out of perhaps 1,000 boys. It is very rare among women (fortunately), but it does exist sometimes, to judge by the extraordinary colours you see some women wearing.

In most text-books the Young-Helmholtz theory is given. This supposes that there are three sets of nerves in the eye, one set being sensitive to red, the other two to green and violet. I suppose why it has persisted so long is because three-colour printing is successful. It cannot possibly be right. It supposes that colour blindness is due to the absence of one set of nerves or partial atrophy. Now, if a set is missing, there should be light loss also, see fig. 1. There certainly is no light loss (except when the spectrum is shortened). Suppose the red nerves are missing, bright red would be matched with a darkish green. I've never seen this done ; a colour-blind person will match a bright red with a bright green. There is no light loss.

A shortened spectrum is sometimes met with, like a person who cannot hear very high notes. I had one case (see no. 7 spectrum)

who had a shortened violet end. He wore dark violet socks and, as I expected, he insisted that they were black Dr. Edridge Green introduced a theory which is very fully explained in his book *Colour Blindness* in the International series and more briefly in his book on *Memory*, both of which are most interesting and should be read by anyone intending to take up this study. I very soon abandoned the Young-Helmholtz theory and worked on the lines of Edridge Green, and I had some correspondence with him and a long talk.

To put it as briefly as possible, the inability to distinguish colours is entirely mental, like so many of our senses, i e., brain, not eye. If the eyes are defective, you may get some colour blindness such as tobacco amblyopia.

Take music, for instance. Most people easily recognize 12 or so points of difference in an octave ; a musician, however, recognizes far more ; some people have such poor perception that they do not

FIG. 1.

notice if singing is out of tune. One of my friends, a bell-ringer, was never certain which was three and which was four on six handbells. The two bells are a semitone apart and I always had to tell him which was which. Such people's perception is mental ; they hear the noises as well as anyone. So it is with colour.

The colour sense has probably developed gradually. The pre-historic man was probably monochromatic, or nearly so. Later, he began to notice a difference between the ends of the spectrum, that is, he would notice a bit of red and violet ; then the differences would become more pronounced and he would be a 2 unit with a neutral band between the red and violet. Perhaps Noah was at this stage (?) as he makes no mention of colour in the rainbow. Homer, I believe, only mentions two colours. As development proceeded, the neutral band would get less and less and yellow would be seen ; then 4 points, R, Y, G, V, then 5, R, Y, G, B, V, and finally, normal sight, 6 points of difference, R, O, Y, G, B, V. Of course, one can mark out more

than six, such as, RO, OY, YG, etc., but the ordinary man is satisfied with six.

Sometimes people see seven colours, but it is very rare. I've only come across three. They are real experts. They call blue-green sky-blue. It was curious that Newton was rather colour blind and got his assistant to mark out the colours. He happened to be a 7 unit and so it got into the text-books that there were seven colours in the spectrum.

The most common cases of colour-blind people are 2 units with a neutral band between, which they call yellow and blue. These people are dangerous, as they may not distinguish between red and green lights. Three units are not to be trusted either, as in bad light, mist or rain, they may confuse red and green as they are, to them, adjacent colours.

Two units are often quite good at naming colours correctly. Below I give some spectra of a few of my cases and also the colour matches they made. Note particularly no. 6. He was getting on for being a monochromatic. He took no interest in colour and painted an extraordinary copy of a coloured picture. I got many paintings done, but unfortunately they are lost.

Method of Testing.

Using the Edridge Green colours, there are four standard test wools. These are no. 1, orange ; no 2, bluish green ; no. 3, violet ; no. 4, red. To these I generally added a fifth—rose pink.

No. 1 is first given, and the boy is told to name it and to pick out wools of the same colour, whether light or dark.

As to the naming, surprising answers are sometimes given. A 2 unit may call it yellow, red or perhaps green. I once heard it called heliotrope ! This was simply colour ignorance, which, by the way, is rather common. The reason may be that people's standards of colour are not so good. Thus, they talk of red hair. What a shock you would get if you met anyone with pure spectrum-red hair ! I would suggest the following as standards :

Red : claret or ruby glass.
Orange : the hot glow of a coal fire.
Yellow : buttercup.
Green : olive (grass is too yellowish).
Blue : sky.
Violet : the flower violet.

Some people imagine violet as purple, but purple is a mixture of red and violet.

To continue the testing. The 2 unit will select pinks, yellows, reds, light greens, *all of the same shade*; it is difficult to get him to mix up light and dark shades. According to the Young-Helmholtz theory, this orange test should appear somewhat dark to a 2 unit and he should, therefore, match a darkish green with it. Well, he won't, nothing will induce him to; there is no light loss. He is really more influenced by shade than by colour.

The other standards are used to verify the class to which he belongs. A 5 unit will probably put a pink with no. 1 and will talk about reddish-yellow.

Three and 4 units will mix up browns and yellows and of course blues and violets.

The rose pink will confirm the 2 unit with a neutral band, as he will match light blues with it, for although to the 6 unit, rose pink is a mixture of the end colours, red and violet, to the 2 unit, as his only colours are the end ones, it will appear grey, or white, which is the same as his neutral band. A 3 unit may also make this mistake.

After the wool test, if I had found colour blindness, I proceeded to use the spectroscope in the following way. In the focal plane of the eyepiece, I placed a narrow vertical slit and set the telescope so that only yellow was seen. I asked the boy to name the colour (the 2 unit always says yellow) and then moved the telescope slowly towards the red end, say, to the right, stopping when a new colour came in view. The 2 unit goes right on to the end. Read the vernier. When told to go slowly to the left, the 2 unit will stop at the beginning of his neutral band and say, " It goes white here ", and so on to the end. In this manner the whole spectrum is plotted.

A doctor once asked me to map his spectrum. He marked out seven colours. I knew he was not a 7 unit as he called blue-green, blue-green and not sky-blue. On showing him a blue-green wool, he named it correctly, whereas a 7 unit would have laughed at the idea of its being a mixture and would have said it was pure blue.

I then started to ask him to set the slit at ends of various colours, dodging about, such as left end of orange, right end of blue, left end of red, right end of violet, and so on. I then pointed out to him that his blue and violet joined up very nicely and there was no indigo, he was no 7 unit.

Here are a few spectra.
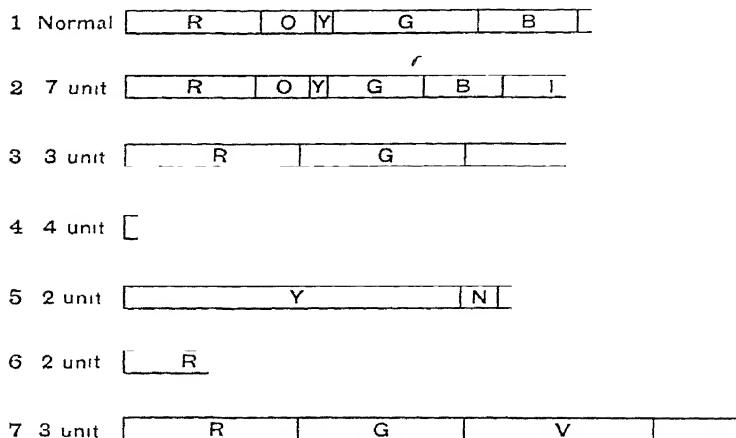
FIG 2.

Studying these will give the key to the various classes, and causes of the mistakes made.

No. 1. Normal sight. To repeat, Test 1 is orange ; Test 2, blue-green ; Test 3, violet , Test 4, red.

No. 2. A 7 unit will rearrange a little to make room for his indigo, so his blue will cover the 6-unit blue-green, which of course is why he will call blue-green pure blue.

His selections were : Test wool 1 he called orange and pulled out 3 oranges, 1 gold, 1 very dark reddish-orange.

Test wool 2 he called sky-blue and picked out 1 correct and 1 dark blue-green.

Test wool 3 he called indigo-violet and selected 3 correct, 2 blue, 1 purple.

Test wool 4 he called orange-red and selected 2 correct and 10 reds.

No. 3 A 3 unit. Test wool 1. He picked out 3 oranges, 1 yellow-orange and 1 yellow-green.

Test wool 2. Selection, 2 greens, 7 yellow-greens, 1 green-brown, 1 grey, 1 rose.

Test wool 3. He picked out 1 rose, 9 blues and 5 violets.

Test wool 4. He selected 4 reds, 1 dark orange and 2 browns.

Test wool 5 (rose). His selection was 2 rose, 1 blue, 1 violet.

It will be seen that browns and greens bother him on the one hand and blues and violets on the other.

No. 4. A 4 unit. He called Test 1 yellow-red and matched 3 oranges and 1 yellow-orange with it.

Test 3 he called blue and he put with it 6 blues, 4 violets, 1 blue-violet and 1 blue-green.

He called Test 2 green and selected 3 blue-greens

Test 4 he named red and put 5 reds and 3 pinks with it.

Oranges and yellows, blues and violets are his chief mistakes.

No. 5 An ordinary 2 unit. He called Test 1 red and matched it with 5 reds, 1 orange, 1 orange-brown, all the same shade.

Test 2 he called grey (right on his neutral band). He put with it 9 blue-greens, 1 yellow-green, 1 pink, 2 greens, 2 grey and 2 grey-violets.

Test 3 he was rather good at and picked out 6 blues, 5 violets, 1 blue-violet and 1 blue-green quickly.

Test 4 he named as red and selected 4 reds, 10 browns, 1 orange-brown.

His selections are typical and agree with all I have said about 2 units.

No. 6. A 2 unit with a very large neutral band. He called Test 1 light brown and put with it 4 greeny-yellows, 6 yellow-greens, 2 oranges, 2 browns (light) and 1 red.

No. 2 Test he called grey and picked out 6 greys, 5 blue-greens, 1 green, 2 yellow-greens, 1 orange and 2 browns.

He called No. 3 Test blue and put with it 6 violets, 1 grey-violet, 2 blue-violets, 10 blues and 8 rose pinks.

No. 4 he called red and with it he put 2 greeny-yellows, 10 browns and 5 reds.

A very interesting case.

No. 7. A 3 unit with shortened violet, the " black " sock hero. Test 1 he called reddish-orange and selected 5 oranges, 5 yellows and 1 pink. Test 2 he called green and selected 4 blue-greens, 8 yellow-greens, 6 greeny-yellows and 3 browns.

Test 3 he called blue and selected 1 violet and 9 blues.

Test 4 he called red and selected 11 reds, 4 pinks, and 1 brown.

These alone are just 7 of the 30 or so I recorded and are very typical of the various classes.

Five units do not much matter ; they get confused only with oranges and yellows ; they do not see orange as a separate colour and merely consider it as a mixture of yellow and red. I think this class is very, very common.

I hope this somewhat brief account will arouse interest and cause many to take up this very interesting study. I am confident that any who take it up will find out that the Young-Helmholtz theory will not do and that the Edridge Green theory explains every observed detail.

LESSON NOTES : ELECTROLYSIS FOR SCHOOL CERTIFICATE

By A. MERRICK
Bootle Secondary School

PART I

A. Attention is first drawn to objects in daily life which are either prepared by electrolysis, or in which an essential step in their preparation is electrolytic, e.g., (i) the chromium-plated parts of cycles, car radiators, bath taps, and so on ; (ii) the gramophone records they play, made from a " master " prepared by electroplating a graphited blank on which the record had been cut [*S.S.R.*, No. 77, p. 19] ; (iii) the " Milton " used as an antiseptic wash ; (iv) the H.C.C. wires of their wireless sets ; (v) the chlorine-purified Thames water so many drink. One or more of these, or similar instances, should appeal to the personal experience of each student.

B. The cells shown in the diagram are then one by one reviewed ; the several electrolytes, electrodes, and colours carefully noted and exactly recorded.

C. The whole set is then carefully assembled in series, a diagram prepared on the blackboard and attention drawn to the fact that the negative of one cell is part of the same conductor as the positive of the following cell. The method of applying a desired potential to the series of cells by means of a field rheostat across 230-volt D.C. mains is explained.

D. Everything is checked over again and on switching on the current no reading is got on the ammeter, though the volt-meter across the assemblage reads 230 volts.

A rapid test with an accumulator and galvanometer (i.e., an ammeter) by means of portable leads (and test prods) shows that it is the water cell which alone is not yielding any visible proof of being a conductor.

E. Concentrated sulphuric acid, in moderate amount, is then poured into the third limb of the water cell. Attention is drawn to the way refraction effects enable us to follow its descent down the tube

Electrodes

Cells

Electrolytes

A

Pt +

Pt −

I
Water
+ H_2SO_4

Manufacture of Hydrogen
for Margarine etc.

Cu +   Cu

II
$CuSO_4$
Solution

Electrolytic
refining

Cu −   Cu

Pt   Cu +

III
$CuSO_4$
Solution

Electro-
plating

Pt −

Pt   Pt +

IV
NaOH
Solution

As I

Pt −

C +

C   Fe

V
Brine

Electrolytic
manufacture of
NaOH & Cl_2

VI
HCl
Solution

Cu   Pt +

VII
H_2SO_4
Solution

Travel
of
+ ions

Pt   Pt +

VIII
Na_2SO_4
Solution

Pt −

Pt −

D C Mains

− +

V

Suggested Lay Out.

and then, as it is watched, it is seen to get to the level of the electrodes and forthwith bubbles begin to come off at both and with increasing speed—so that it becomes necessary to cut down the applied P D. very quickly to keep the bubbling at a convenient rate.

F. Attention is also directed to the fact that the other cells of the series started up at the same time as the water cell did.

G The various effects in the several cells are now tabulated in the following or similar form ; facts, not theories, being recorded and analogous industrial processes named.

TABLE OF ELECTROLYTIC EFFECTS

Cell	+Electrode	Anode Effects	Electrolyte	Cathode Effects	Electrode	Further Notes
IA	Pt	Nil	Lake Vrynwy water	Nil	Pt	What was water becomes dilute H_2SO_4 Hydrogen manufacture for margarine Vol oxygen Vol hydrogen = 1 2 (approx)
IB	Pt	Colourless gas, relights glowing splinter	Dil H_2SO_4	Colourless gas , lit, burns with blue flame	Pt	
II	Cu	No bubbles, anode goes dull and shows signs of wear	CuSO₄ soln	Bright copper deposit on cathode No bubbles	Cu	Copper refining for H C C wires
III	Cu	Anode thins away and possibly breaks off, a greenish colour spreads from it towards cathode	Dil H_2SO_4	Bubbles of hydrogen at first , much later copper deposited when colour has spread to cathode	Pt	(i) Metal from anode travels cathode-wards (ii) Electroplating
IV	Pt	Bubbles of oxygen Red colour spreads towards cathode and then bleaching effect	Na₂SO₄ soln + litmus	Bubbles of hydrogen Blue colour spreads towards anode	Pt	Shows acidity starts and grows at anode and vice versa Alkalinity grows at the cathode
V	C	Chlorine set free (starch iodide papers blued), solution very acid	NaCl soln	Hydrogen set free, liquid goes strongly alkaline	Fe	Manufacture of (i) bleach liquor, (ii) caustic soda, etc
VI	Pt	Chlorine and oxygen mixture, composition depending on conditions *S S R* , No 63, p 340	HCl soln	Hydrogen set free	Pt	Shows supreme importance of degree of concentration of electrolyte

Attention is next drawn to the fact that Faraday found that, with a steady direct current and cells in series,

I. The amount of gas set free or of solid deposited was proportional to the time the current was on.

II. The weights of silver, copper, hydrogen and oxygen set free were in the ratio of 108 : 31·5 : 1 : 8, which numbers are their chemical equivalents ; and from these facts, he drew up his first two laws, in these his own words :—

Law I. " The chemical power of an electric current is in direct proportion to the absolute quantity of electricity which passes."

Law II. " Electrochemical equivalents coincide and are the same with ordinary chemical equivalents."

[Cf. *Experimental Researches*, Article 571, Dent's Everyman's Library.]

Here it will be necessary to point out the change of definition since his day, for nowadays we define our electrochemical equivalent weights as the weights of the substances set free by the passage of one coulomb of electricity, and so our present values are one 96,500th part of Faraday's values ; for one coulomb liberates 0·001118 grams of silver and one gram equivalent of silver is 107·88 grams, which number is 96,500 times the other. So our electrochemical equivalents may be got by dividing the chemical equivalents by 96,500.

Everything so far has been plain sailing, simply noting each landmark as we go along and no theorizing. We now come to seek an explanation of the mechanism of the changes we have noted

PART II

Starting where we left off in Part I, we may draw attention to the phenomena in cells III and IV, and draw the conclusions given in the last column of the table. Someone of thoughtful mind is certain to ask, " If the copper travels from anode to cathode as Experiment III shows it does, what happens to the sulphate part of the copper sulphate, there or in Experiment II ? " He may be told of Whetham's Experiment with solutions of potassium carbonate and potassium permanganate, described in the latter's *Solution and Electrolysis*, p. 217.

Thence we see that in the electrolysis of a solution of a salt there is a movement of metallic matter cathode-wards and of acid radicals anode-wards ; but, says someone, " What about the water ? Doesn't it play any part in what is going on ? "

In answer to this very natural query, Experiment VI may be discussed in light of the facts ascertained and given [*S.S.R.*, No. 63, pp. 340, 341], wherein we read that very dilute hydrochloric acid yields oxygen at the anode and no chlorine; the very concentrated acid yields at the anode chlorine and little or no oxygen; solutions of intermediate strength give mixtures of oxygen and chlorine, depending on the proportions of the solution. Further, it may be pointed out that solutions of hydrofluoric acid are conductors of electricity, yielding hydrogen and oxygen till all the water is gone, when the " dry " acid proves to be a non-conductor : a novel way of drying a liquid.

Thus, therefore, it follows that not only the solute, copper sulphate, but also the solvent, water, must be considered in any adequate discussion of the facts of electrolysis of a salt such as copper sulphate.

At this point it is well to pause and to devote a short talk to pointing out what a wonderful time was the end of the eighteenth century and the whole of the nineteenth century in the world of thought. Arrhenius' *Theories of Chemistry* (pp. 157 *et seqq.*) gives a fair and concise guide of how the work of the botanists, the physical chemist, van 't Hoff, and himself led to his famous theory of electrolytic dissociation. In all this talk it is worth emphasizing that it is a search for truth which is being described, a search worth doing for itself and one which has led to great enlightenment.

Next, with or without such a preface, tell what is now held to be the fact, namely, that in a solution the electrolyte is practically wholly dissociated into positively charged particles and negatively charged particles and that, consequently, as in all the electrostatic experiments they have seen, these particles are respectively and severally attracted and repelled by the oppositely and like charged electrodes when the current is switched on. We may postpone to the VI Form how far the " crowding," or concentration effect of modern theories and Arrhenius' partial dissociation ideas are an earlier and a later way, respectively, of explaining the same set of facts. At the S.C. stage there is not time to touch on this aspect of the matter—further, unless someone raises the question in class, we may postpone the fact that there is evidence for some undissociated molecules [cf. Chemical Society : Annual Reports 1934, p. 65].

We now have to account for the phenomena noted in the actual experiments, and it is best done by the following analogy :—Let us think of a tidal harbour outside of which, at low water, lie a number of craft of all sizes awaiting the chance to enter. Which will get in first

as the tide rises, the smack or the tramp drawing 20 ft. or more of water ? Even so, those ions needing the least voltage for their discharge will be discharged before those requiring a higher voltage, for clearly, as each gram-equivalent needs 96,500 coulombs to pass through the circuit to liberate it, the smaller the voltage this has to be driven through, the less the work done in discharging such an ion and so the more reason why such an ion rather than another is discharged. Just as the tide does less work against gravity in lifting a drifter over the bar than in doing the same to a deep-sea ship.

Applying these ideas to the copper sulphate solution, we first draw a cell with circles in it enclosing the symbols of the ions they represent, Cu^{++}, SO_4^{--}, H_3O^+, OH^- with arrows pointing in all directions indicating random motion, then in a second drawing the same ions are depicted with the attached arrows pointing to the appropriate electrode in each case. Hence we arrive at the following state of affairs :

At Anode.	*At Cathode.*
$OH' + OH' + OH' + OH'$ $= O_2 + 2H_2O$ and (SO_4) remaining undischarged.	$Cu \longrightarrow Cu$ deposited and $4(H_3O)^{\cdot}$ remaining undischarged.
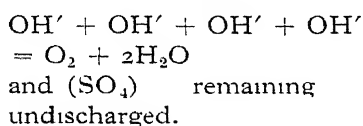
For as Glasstone (loc. cit.) puts it so well in No. 63 of this journal :

When the external E M F. applied to an electrolytic cell is gradually increased, the potential of the cathode becomes steadily more negative and that of the anod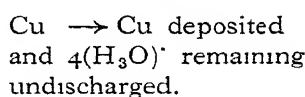e more positive until the deposition potentials of the ions are reached.   Consider, for example, the electrolysis of M-copper sulphate solution containing M-sulphuric acid : the discharge potential of the cupric ions is about 0·33 volt whereas hydrogen gas should commence to be evolved at a potential of approximately − 0 23 volt, allowing for the over-voltage on a copper cathode.   It is clear that copper will be deposited exclusively in the cathode and no hydrogen will be evolved   If the electrolysis is prolonged so that the cupric ions in the solution are almost exhausted, the potential will become sufficiently negative for hydrogen evolution to commence.   Should the current be so large that the cupric ions are not brought up to the electrode sufficiently rapidly to satisfy the requirements of the current, according to Faraday's laws, then the potential will become more negative and simultaneous deposition of copper and hydrogen will result   In an ordinary electrolysis of acid copper sulphate solution, neither of the contingencies leading to hydrogen evolution is likely to result

Thence it becomes clear why current density must be considered in electrolysis, for if we push up C.D we push up P D. across the elec-

trolyte layer in contact with the electrode and, as local concentrations are bound to occur in that layer, there will be local P.D.s at various points and not simple uniform P.D , which has possibly something to do with pits, knobs, etc., which often occur in electrolysis.   Hence also the use of stirring the electrolyte mechanically

It is hoped that this way of putting matters may be preferred to the primary and secondary explanation so often given, and, of course, the actual notes will be much shorter than this suggested exposition of the subject matter.

THE EARLY DEVELOPMENT OF THE FROG—I

By G. E. NEWELL, B Sc., Ph.D., and A. J. GROVE, M.A., D Sc.

Department of Zoology, Queen Mary College, University of London

INTRODUCTION

IN a previous article a brief description was given of the early development of Amphioxus and it was suggested that it might serve as a basis upon which the general features of chordate development might be founded. This was not necessarily because it represents a primitive condition but rather that it serves to bring into relief some of the essential points in craniate development. It will be recalled that immediately subsequent to fertilization the cytoplasm of the egg of Amphioxus becomes visibly differentiated into different regions which from that moment onwards play a fixed and determined part in future development. That is to say, these cytoplasmic areas (containing organ-forming substances) each give rise to definite and particular structures in the embryo and one important rôle of cleavage is the distribution of their organ-forming substances (by their inclusion in particular blastomeres) to their definitive positions in the blastula. The early stages of craniate development follow, in the main, the same general lines as those indicated for Amphioxus but with at least one important difference. The differentiation, or determination of the fate of the cytoplasm of the cells does not take place until a later stage of development—usually towards the end of cleavage—and the different types of cytoplasm being now confined within the cell membranes of the blastomeres are re-distributed in the embryo by streaming movements of the cells. If this difference is borne in mind then it will be realized that many of the important developmental processes in which the craniates differ from Amphioxus are but necessary modifications for the attainment of a similar result.

Considerable variation is met with in the craniates themselves, especially in the earlier stages, but many of the differences may be attributed to the interplay of physical and chemical factors whose influences have been investigated by experimental methods.

The development of the frog,[1] which is the next example usually taken after Amphioxus, provides an instance of a moderately telolecithal ovum, the embryo hatching as a larva (tadpole) in a much more advanced stage of development than the gastrula larva of Amphioxus.

THE EGG

Each egg is formed in a follicle in the ovary and when released into the body cavity to pass into the oviduct, is a spherical body about 1·6 mm. in diameter. Roughly one-half of its surface is a deep brownish-black colour due to the presence of a superficial layer of pigment granules. The other half is of a much lighter colour, and it is in this half that the greater part of the yolk is aggregated so that the ovum is telolecithal and the large nucleus (germinal vesicle) lies in the upper part of the pigmented half. This unequal distribution of the pigment also indicates the polarity of the egg, the pigmented pole being the animal pole and the lighter coloured one the vegetative pole.

Fig 1 —The unfertilized Egg enclosed in its Membranes (Animal pole uppermost)

album , albumen ; *A P* , animal pole ; *pigm ½*, pigmented half , *vit memb* , vitelline membrane , *V P* , vegetative pole , *ylky ½*, yolky half

The eggs are released from the ovary as primary oocytes and the first stage in maturation occurs during the passage of the egg down the oviduct. When the egg leaves the follicle it is surrounded only by a thin vitelline membrane and the first polar body remains within this membrane. The point of extrusion of the first polar body is marked by a small depression on the surface of the pigmented area. During their passage down the oviducts the eggs are coated with albumen which swells in contact with the water on deposition, forming the familiar frog spawn.

[1] Although the English Frog (*Rana temporaria*) is the one used in England for practical work, most of the embryological investigations have been carried out on other Anura. There is no reason to believe that their development differs in any fundamental way from that of the common frog, and the following account is a summary of those features which are common to the development of all anurans.

FERTILIZATION

It is in this form, as secondary oocytes, that the eggs are laid and, since the male immediately deposits the spermatozoa upon them, fertilization occurs at once, usually before the albuminous covering has had time to swell up. The entry of the spermatozoon into the egg appears to induce the completion of maturation, for the second polar body is extruded almost immediately. At the point where the head of the spermatozoon comes into contact with the vitelline membrane, the surface of the egg is raised into a small protuberance into which the spermatozoon penetrates. The passage of the sperm nucleus (male pronucleus) through the cytoplasm is marked by the carrying in with it of some of the pigment granules from the surface and it traverses a definite path (the sperm path) towards the nucleus (female pronucleus) of the now mature egg. This path is commonly straight, passing directly towards the female pronucleus when that nucleus is in the
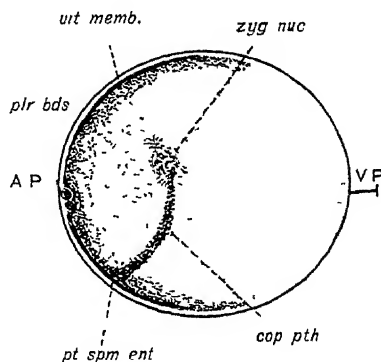
FIG 2 —Vertical section through a fertilized Egg   (In this and subsequent figures the embryonic axis is indicated by an arrow.)

A P, animal pole ; *cop. pth.*, copulation path ; *plr. bds*, polar bodies ; *pt spm ent*, point of entry of the spermatozoon ; *V P.*, vegetative pole ; *vit memb*, vitelline membrane ; *zyg nuc*, zygote nucleus

middle of the cytoplasm, but may, on occasion, when the female pronucleus is excentrically placed, consist of a preliminary " penetration path " and a subsequent " copulation path " inclined at an angle to the former. As will be seen later, the direction of the sperm path is important in cleavage.
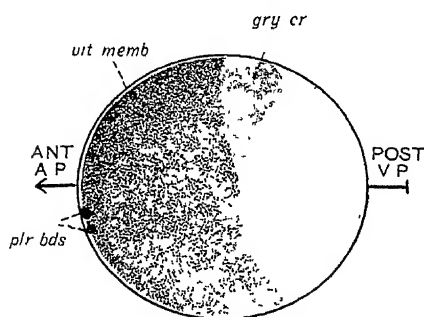
FIG 3 —Side view of a fertilized Egg

A P, animal pole ; *ANT*, anterior ; *gry cr*, grey crescent ; *plr. bds*, polar bodies ; *POST*, posterior ; *vit memb*, vitelline membrane ; *V P*, vegetative pole

The penetration of the spermatozoon causes certain changes in the distribution of the external pigment in addition to the carrying in of pigment by the spermatozoon. At a point diametrically opposite the point of entry, there is an inward flux of pigment and water which results in the formation on the

surface of a crescentic area of a greyish instead of the normal dark colour   This development is accompanied in some amphibian eggs by streaming movements in the pigment.

SYMMETRY

The appearance of the grey crescent on the surface of the egg has materially altered its symmetry.   Before fertilization took place the arrangement of its parts was, apparently, radially symmetrical about an axis (the egg axis) passing directly from the animal to the vegetative poles.   Now, however, a definite bilateral symmetry[1] has been imposed about a plane passing through the middle of the grey crescent and the two poles.   Normally, this marks the plane of the first cleavage division so that it divides the egg into right and left halves, but actually the position of the first cleavage plane is determined by other conditions (see below).

Another development which follows the appearance of the grey crescent is that the orientation of the future embryo is now established, for the grey crescent marks the position of the dorsal lip of the blastopore when it is first formed, and, consequently, of the dorsal surface of the early embryo   It is, therefore, possible now to indicate the main axis of the future embryo though, for the present, the egg always assumes a position with the animal pole uppermost, however it may be displaced. This is because the egg has become free from the vitelline membrane as a result of a slight shrinkage due, in all probability, to the extrusion of a little water.

CLEAVAGE

Cleavage is of the holoblastic, unequal type, for the quantity of yolk present is sufficient to cause considerable hampering of cleavage in the vegetative hemisphere.

The first cleavage plane is meridional and its position is determined by the direction of the terminal portion of the sperm path.   If the penetration path is in a straight line with the copulation path, then the first cleavage plane passes through the centre of the grey crescent, but if the female pronucleus is excentric and the copulation path is inclined to the penetration path, then the first cleavage plane may pass to one

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[1] There is, however, much evidence in support of the view that the position of the grey crescent has already been determined before the entry of the sperm. This merely causes its presence to be revealed.   The sperm path of the sperm happens to coincide, in the vast majority of cases, with the plane of bilateral symmetry.

side of the grey crescent, since it always coincides with the plane of the copulation path or, more accurately, the equator of the first spindle. This does not, however, interfere with the symmetry of the future embryo, for the crescent will be divided at a subsequent cleavage. The first cleavage divides the fertilized egg or zygote into two blastomeres which remain closely adposed to one another, the cleavage being indicated on the surface by a meridional furrow which is more pronounced in the pigmented hemisphere than in the yolk-containing region. Even before the furrow of the first cleavage plane has extended completely into the vegetative region, the second division has commenced. This is also meridional but at right angles to the first. It extends rapidly through the animal hemisphere and more slowly
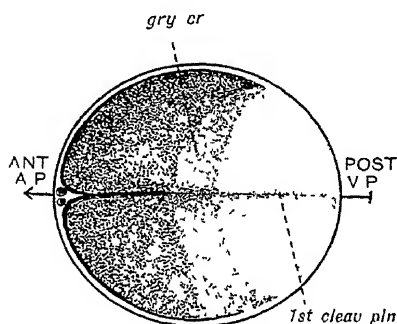
FIG 4 —Dorsal view of the two-celled Stage

A P , animal pole , *ANT* , anterior , 1st *cleav pln.*, first cleavage plane , *gry cr* , grey crescent , *POST* , posterior , *V P* , vegetative pole
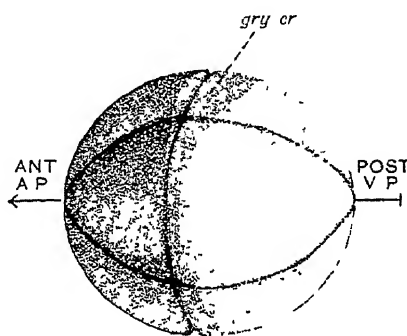
FIG. 5 —The eight-celled Stage (Vitelline membrane omitted.)

A P , animal pole , *ANT* , anterior , *gry cr* , grey crescent , *POST.*, posterior ; *V P* , vegetative pole

through the vegetative, producing four blastomeres. The third cleavage plane is latitudinal and is situated well above the equator of the egg. This produces eight blastomeres, four pigmented micromeres at the animal pole and four large yolk-containing macromeres at the vegetative pole. The fourth cleavage division is meridional and divides each of the micromeres into two, producing eight, and eventually does the same to the macromeres. But the fact that the third cleavage division has separated the almost yolkless pigmented micromeres from the yolk-containing macromeres has removed from the former the hampering effect of the yolk to the passage of the cleavage planes. Thus, although for a time the cleavage planes follow an orderly sequence of alternating meridional and latitudinal directions, the division of the micromeres proceeds much more rapidly than that of the macromeres

with the production of a blastula, the upper hemisphere of which is composed of small externally pigmented cells and the lower of large yolk-containing cells, the blastocoel being excentric. In all these happenings the position of the grey crescent remains indicated by the colour of the cells formed within its limits

THE BLASTULA

If a sagittal section of such a blastula is examined, it will be found that in the upper or animal hemisphere, surrounding the blastocoel, the wall of the blastula consists of several layers of small cells, the outer ones
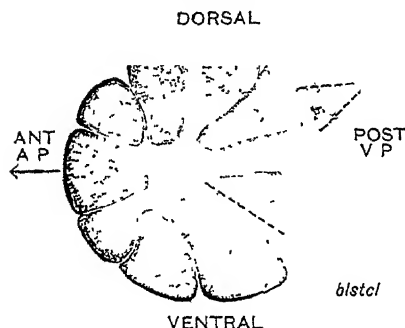
FIG. 6 —Vertical Section through an early Blastula

A P., animal pole ; *ANT* , anterior , *blstcl* , blastocoel ; *macrms* , macromeres ; *POST.*, posterior , *V.P* , vegetative pole.
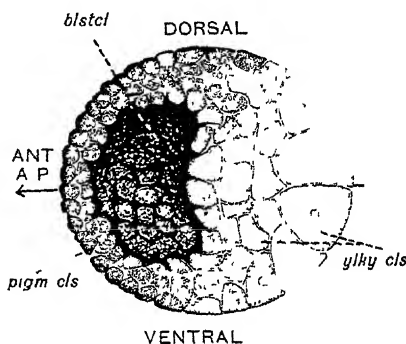
FIG 7 —Sagittal half of a late Blastula

A P , animal pole ; *ANT* , anterior ; *blstcl* , blastocoel , *pigm cls* , pigmented cells ; *POST* , posterior , *V P* , vegetative pole , *ylky cls* , yolky cells

of which have pigment on their external surfaces. The lower, or vegetative hemisphere, is composed of a mass of large yolk-containing cells.

Although from a mere inspection of the late blastula it would appear that there is little distinction between its cells except in size and yolk content, it has been shown that a potential differentiation of the cells has already set in. That is to say, the rôle which the cells will play in future development was already being determined during and towards the end of cleavage, and it has been possible to map out on the surface of the blastula, cell areas of differing potentialities [1] (Figs. 8,

[1] Our knowledge of the positions occupied on the walls of the anuran blastula by the different kinds of cells is largely due to Vogt and his fellow-workers who followed up and extended results obtained by the Spemann school who worked largely on urodele embryos Vogt succeeded in perfecting a technique of intra-vitam staining by means of which small areas on the wall of the blastula were coloured with various harmless dyes. In this way the different areas were recognizable for a considerable period and the parts that they played in development was followed.

9 and 22).   The names given to these areas refer only to their *normal* potentialities for, as will be seen later, the embryo is still, at this stage, capable of considerable re-adjustment if it is interfered with by damage or other means.   To put it another way, the determination of the cell areas (with the important exception of the cells of the grey crescent) is still labile, and for this reason they are referred to as " presumptive areas." The mapping out of the presumptive areas has in many amphibia been carried out in great detail, but the following main areas may be distinguished.   The presumptive ectoderm occupies almost all

FIG. 8.—Side view of Blastula of *Bombinator* showing presumptive areas mapped out
(Based on Vogt)

ANT , anterior , *d lp* , dorsal lip of the blastopore , *endod* , endoderm , *epid* , epidermis ; *L B* , line marking future lips of the blastopore , *L I* , limit of invaginated material , *L P* , lateral plate , *mesd* , mesoderm , *nrl plt* , neural plate , *ntchd* , notochord , *POST* , posterior , *prechd endod* , prechordal endoderm , *S* , somites

of the animal (anterior) half of the blastula and is subdivisible into presumptive epidermis, which lies along its ventral and ventro-lateral parts and presumptive neural (medullary) plate, a broad band stretching over the antero-dorsal and lateral parts   Posterior to this (i e , nearer the vegetative pole) on the dorsal surface, is a smaller area with two lateral horns passing down on each side of the blastula.   This is the presumptive notochord. The presumptive mesoderm lies chiefly in two lateral areas behind the horns of the notochordal area.   The two mesodermal fields are separated in the mid-dorsal line by the noto-chordal cells but are continuous across the mid-ventral line, so that the

mesoderm lies in a crescentic area in much the same relative position that it occupies in the blastula of Amphioxus. The remainder of the vegetative (posterior) half is occupied by the large yolky endoderm cells.

It will be realized from this description that the future axial structures lie in broad bands transverse to the body axis. That is, they are different not only in position, but in shape, from the structures to which they will give rise in the later embryo. The next important step in development is the re-arrangement of these presumptive areas so that they come to occupy their definitive positions and proportions in the
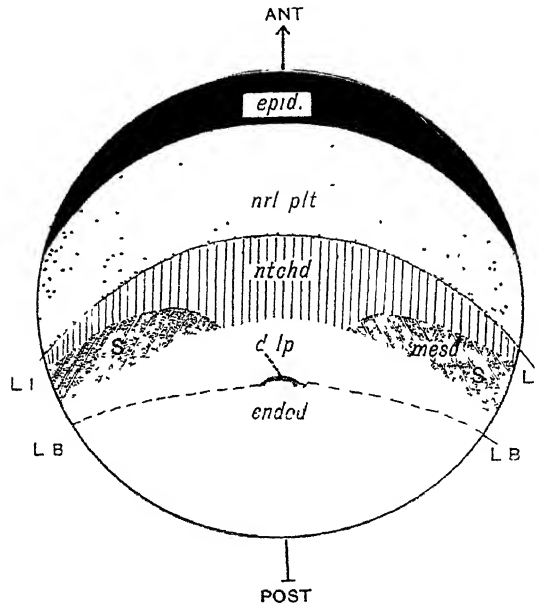
FIG. 9.—Dorsal view of Blastula of *Bombinator* showing presumptive areas mapped out   (Based on Vogt)

ANT., anterior ; *d lp* , dorsal lip of the blastopore ; *endod* , endoderm ; *epid* . epidermis ; *L B* , line marking future lips of the blastopore ; *L I* , limit of invaginated material ; *mesd* , mesoderm ; *nrl plt* , neural plate ; *ntchd* , notochord ; *POST* , posterior ; *S* , somites

embryo. This process is, of course, gastrulation but, because of the appreciable quantity of yolk present, it does not take place by straightforward invagination, as in Amphioxus, but by more devious means.

GASTRULATION

Seen from the outside, gastrulation appears to consist of the progressive growth of the pigmented cells over the lighter-coloured yolk-containing cells until all but a small circular patch, the yolk-plug

(marking the position of the blastopore), is covered. Actually, gastrulation is far more complicated than this and is due to several types of activity going on at one and the same time, but the result is, of course, that the presumptive ectoderm comes to enclose the presumptive noto-

DORSAL
ntchd   archtn
nrl plt

ANT
POST

blstcl

endod
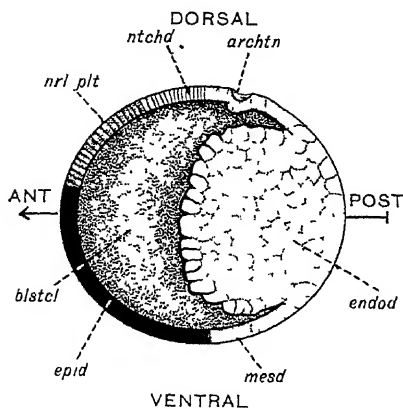
epid   mesd
VENTRAL

FIG 10 —Sagittal half of an early
Gastrula

DORSAL
ntchd
nrl plt

ANT
archtn
POST

blstcl

endod
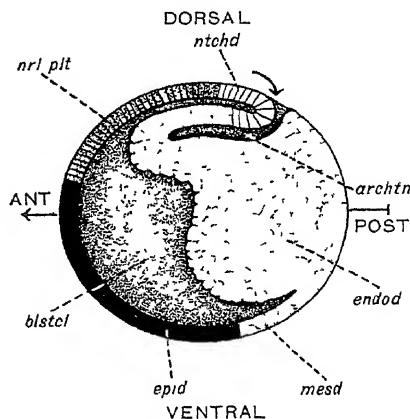
epid   mesd
VENTRAL

FIG 11 —Sagittal half of a later
Gastrula

ANT, anterior ; *archtn*, archenteron ; *blstcl*, blastocoel ; *endod*, endoderm ; *epid*, epidermis ; *mesd*, mesoderm ; *nrl plt*, neural plate ; *ntchd*, notochord ; *POST*, posterior.

ntchd
DORSAL
nrl plt
archtn

ANT
POST

endod

epid
mesd
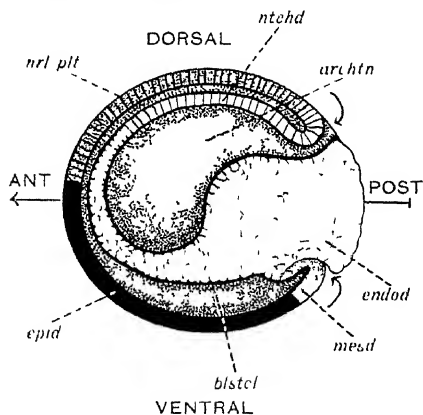
blstcl
VENTRAL

FIG. 12 —Sagittal half of a Gastrula
at a later stage than Fig 11

nrl plt   DORSAL   ntchd
archtn

ANT
ylk plg
POST

mesd

epid
endod

blstcl
VENTRAL

FIG. 13.—Sagittal half of a nearly
completed Gastrula.

ANT., anterior ; *archtn*, archenteron ; *blstcl*, blastocoel ; *endod*, endoderm ; *epid.*, epidermis ; *mesd*, mesoderm ; *nrl plt*, neural plate ; *ntchd.*, notochord ; *POST.*, posterior ; *ylk plg*, yolk plug

chord, mesoderm and endoderm. Gastrulation is due to a remarkable series of mass migrations of cells which may be termed formative movements and is not caused by the localised production of new embryonic material as was formerly supposed. It is essentially a

re-arrangement of material already present, and it has been shown that
whilst the cells continue to divide actively they do so at more or less
the same rate throughout the whole embryo.   There is thus *at this
stage* no special region of " proliferation " in the frog or, for that matter,
in any other vertebrate embryo.

Although during normal development the various formative move-
ments are perfectly integrated, it has been shown by various surgical
experiments and by observation of
isolated living portions that the effects
are, to a large extent, independent of
one another, and they can thus be con-
veniently described separately.   Firstly,
the smaller cells of the dorsal side of
the animal (anterior) half of the
blastula begin to migrate towards the
posterior end and spread out over the
cells of the vegetative (posterior) half.
Then, along a small crescentic area
(grey crescent cells), on the dorsal side,
some way behind the posterior margin
of the presumptive notochord, the cells
start to roll over and migrate inwards
beneath the outer layers.   In this way
there is formed a crescentic groove, bounded in front by the
intucking notochordal cells and behind, by the endodermal cells.
This groove is the beginning of the archenteron and its anterior
margin is the dorsal lip of the blastopore.   Soon the area of in-
tucking extends laterally so that the groove becomes a wide crescent
with backwardly projecting horns (lateral lips).   Meanwhile, as
fresh material rolls inwards over the lips of the blastopore by the
migration of cells from the animal half, the groove becomes deeper
and deeper so that the archenteron soon forms an extensive cavity and,
at the same time, the blastocoel becomes diminished.   Eventually, the
blastopore becomes a complete circle by the meeting of the lateral lips
on the ventral side and after this it becomes progressively smaller by
gradual contraction of its margins.   However, even when fully formed,
the archenteric cavity does not extend far into the ventral part of the
gastrula because of the accumulation there of the large yolky endoderm
cells, some of which (yolk-plug) also lie between the archenteric cavity
and the ventral lip of the blastopore.   Whilst the intucking (invagination)

Fig 14 —A purely diagrammatical
horizontal section of a Gastrula
showing Mesoderm and Endoderm
being invaginated at the lateral lips
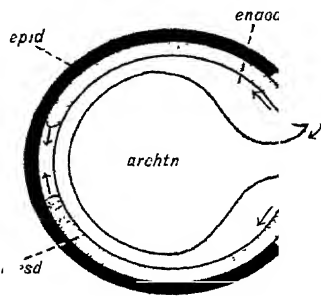of the Blastopore

archtn , archenteron ; *blstp,*
blastopore ; *endod* , endoderm ;
epid , epidermis , *mesd* , mesoderm

of cells over the lips of the blastopore has been taking place, the gradual external spread of the small cells over the yolky cells has continued without interruption and the blastopore becomes progressively carried to the posterior end, so that by the time the ventral lip is established the blastopore is seen as a circular aperture near the original vegetative pole. Gastrulation is, then, brought about by three *main* processes, *overgrowth* (epiboly) or spreading of the cells of the animal half over those of the vegetative half, *intucking* (invagination) of material around the margins of the blastopore and by *contraction* of the margins (lips) of the blastopore. These movements are, however, accompanied by others which result in a gradual extension in length and a convergence
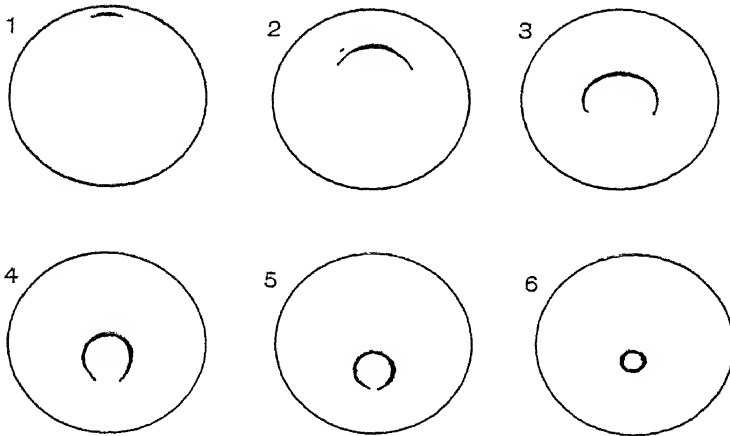
FIG 15 —Successive stages in the development of the Blastopore as seen from the vegetative pole (i e , a posterior view).

towards the mid-line of the presumptive areas of the axial structures of the embryo (presumptive neural plate, notochord and somites) and an extension in all directions of presumptive epidermis followed by an expansion of the lateral plate mesoderm when it has become enclosed. But, despite this great extension of the epidermis, some of the yolky cells are not enclosed until a relatively late stage in development and protrude through the blastopore as the yolk-plug.

The chief result of gastrulation is that the presumptive areas on the wall of the blastula undergo changes in shape and come to lie in their definitive positions in the embryo.   Thus, the material first carried in at the dorsal lip is endoderm (pre-chordal endoderm).   It forms the extreme anterior end of the archenteric wall and remains continuous behind with the yolky endodermal cells which at this stage are not yet

enclosed. They later form the sides and the floor of the archenteron. The next material, in order, to pass inwards at the dorsal lip is presumptive notochord. It soon forms a strip of cells in the roof and is continuous in front with the anterior (endodermal) wall of the archenteron. Presumptive mesoderm begins to be invaginated as the area of intucking extends to the lateral lips. It passes inwards beneath the presumptive ectoderm and comes to lie between this and the endoderm which has meanwhile become enclosed to form the sides of the archenteron. It will be remembered that the vegetative hemisphere of the blastula, unlike the animal hemisphere, consisted of a solid mass of yolky endoderm cells. Mo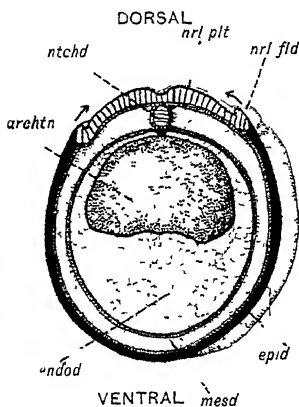st of these are not involved in the invagination process but become enclosed as a result of overgrowth by the cells of the animal half, so that in the completed gastrula they form a piled-up mass in the floor of the archenteron. With the completion of the blastopore, the mesoderm of the ventral surface is invaginated at the ventral lip It will, of course, be realized that the sequence given above merely indicates the order of cell migration ; the process of migration is a continuous one.

FIG. 16.—The anterior half of a late Gastrula (Neurula)

archtn , archenteron ; *endod.*, endoderm , *epid* , epidermis ; *mesd* , mesoderm , *nrl fld* , neural fold , *nrl. plt* , neural plate , *ntchd.*, notochord

Another effect of gastrulation is that, owing to the migration of cells to the mid-dorsal line and the general stretching of the animal half of the embryo, the roof and sides of the blastocoel become thinner, but when gastrulation is completed the original thickness is re-established, though now the cells are arranged in two definite layers above and around the sides of the archenteric cavity, the line of demarcation between them being the remains of the now nearly-obliterated blastocoel.

Gastrulation also causes a shift in the centre of gravity of the embryo which, in the blastula stage, floated with the animal pole uppermost. This was because the blastocoel, a fluid-filled cavity, lay almost entirely within the animal half and rendered it lighter than the vegetative half which was occupied by cells full of heavy yolk. The development of the archenteron within the dorsal part of the embryo gradually reduces the blastocoel, and the embryo, which is free to

rotate inside the vitellin membrane, swings round until it lies with the new cavity, the archenteron uppermost , that is, until the embryo axis is horizontal.

THE ONSET OF DIFFERENTIATION

It will be useful at this point to contrast the methods of differentiation of the frog embryo with those noticed in Amphioxus.   In that example, on completion of the protoplasmic streaming, after fertilization, the fate of the different cytoplasmic regions was fixed and, if a portion of the egg was removed, then the embryo was deficient in some particular feature.   In the frog, however, the determination of the embryonic regions is not final (as will be seen later) until the completion of gastrulation.   Yet, there is a progressive determination and a gradual mapping out of the main regions from the time of fertilization onwards. For example, fertilization imposes bilaterality and the first cleavage plane normally determines the right and left halves of the embryo, but the embryo can still re-adjust itself to injury as is shown by the experiment of separating the first two blastomeres.   Each develops into a smaller but otherwise perfect embryo.   Final determination at this stage (and even much later stages) is confined to the grey crescent, the cytoplasmic precursor of the presumptive notochord and mesoderm. Thus, if a lateral or a dorsal half of an embryo in the two-celled, early cleavage, or blastula stage, is sliced off it will so re-adjust its growth that a normal embryo results, whereas the separated ventral halves either shrivel up and die or, at best, produce ventral structures only.   That is, only those portions of the embryo which contain some of the grey crescent material have the power of regulating their development.

THE FORMATION OF THE NEURAL TUBE

By the conclusion of gastrulation the presumptive neural plate area has come to occupy an elongated pyriform tract along the length of the mid-dorsal region.   It now constitutes the neural or medullary plate from which the brain and spinal cord will be developed.   Along the edges of the medullary plate appear the neural folds and between them the medullary plate sinks downwards because of their progressive uprising and incurving towards the median line.   Eventually, the folds meet and fuse with the formation of the neural tube lying beneath the re-formed ectodermal surface and above the notochord.

The closure of the neural tube begins just in front of the mid-region and proceeds both anteriorly and posteriorly.   At the front end, the
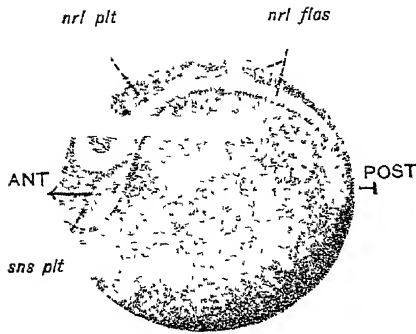
13

FIG. 17.—Antero-lateral view of a late Gastrula (Neurula)

ANT., anterior ; *nrl. flds* , neural folds ; *nrl plt* , neural plate ; *sns. plt* , " sense plate " , *POST* , posterior.
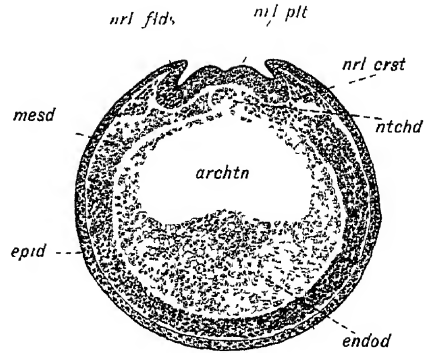
FIG 18 —Transverse section of a Neurula showing the separation of the Mesoderm from the Endoderm

archtn., archenteron , *endod* , endoderm ; *epid* , epidermis , *mesd* , mesoderm , *nrl. crst* , neural crest , *nrl flds* , neural folds , *nrl plt* , neural plate , *ntchd* , notochord
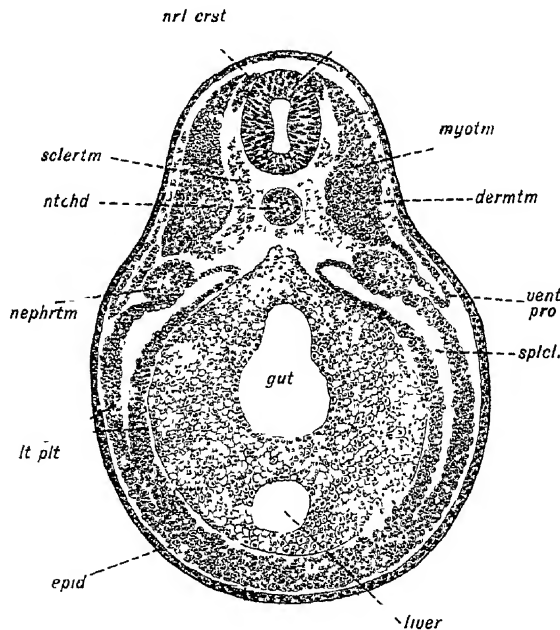
FIG. 19 —Transverse section of an Embryo through the anterior trunk (mesonephric) region showing the differentiation of the Mesoderm

c.n s , central nervous system , *dermtm* , dermatome ; *epid* , epidermis ; *lt. plt* , lateral plate mesoderm , *myotm* , myotome ; *nephrtm.*, nephrotome , *nrl crst* , neural crest ; *ntchd* , notochord , *sclertm* , sclerotome , *splcl* , splanchnocoel ; *vent pro* , ventral process of the myotome.

tube remains open for a time as a neuropore, but posteriorly the neural folds extend laterally on each side of the blastopore which, by their closure, becomes enclosed. As a result of this enclosure of the blastopore, the neural canal is in continuity with the archenteron for, by this time the yolk plug has been withdrawn. The communicating channel thus formed is the neurenteric canal.

Because of the pyriform shape of the medullary plate, the neural tube is much wider at its anterior end. This wider end gives rise to the brain and in it, the development of internal ridges soon indicates the three primary cerebral vesicles. From the remainder of the neural tube the spinal cord is derived.

During the differentiation of the medullary plate, there appears along each edge a linear tract of cells as a thickening of the ectoderm and, when the neural tube is completed, they lie along the dorso-lateral surface of the tube. These tracts constitute the neural crests and from them are derived the dorsal-root ganglia of the spinal nerves and the ganglia of the somato-sensory components of the cranial nerves. The development of the ganglia is metameric and their positions correspond with those of the differentiating somites.

Further Development of the Notochord

As has been seen above, the chorda cells in the completed gastrula lie, as a narrow sheet of cells, in the mid-dorsal region of the roof of the archenteron. At first they are not very clearly distinguishable from the mesoderm lying on each side, but soon the mesodermal cells become separated from the chorda cells by a narrow cleft. The chorda cells then arrange themselves in the form of a cylindrical rod and the characteristic vacuolated appearance is assumed. Around the cells the notochordal sheath is developed. The differentiation of the notochord commences at the hinder end of the embryo and proceeds forwards.

Immediately below the notochord some of the endoderm cells become arranged in the form of a slender rod—the hypochordal rod—which eventually disappears.

The Further Development of the Mesoderm

At the end of gastrulation, the mesoderm cells lie closely applied, almost like a mantle, to the endoderm cells, but usually clearly demarcated from the ectoderm. Very soon the differentiation between the endoderm and mesoderm becomes apparent also, when it is seen that the mesoderm does not extend right to the front end of the embryo.

It extends as a sheet of tissue, several cells thick, from each side of the notochord almost down to the mid-ventral line, even in the region where the large yolk-containing cells lie piled up in the floor of the archenteron. As development proceeds, a split appears in the mesoderm, the cavity thus formed being the coelom. The split first appears in the dorso-lateral region on each side and progresses ventralwards. Eventually, the two halves of the mesoderm, having now met in the mid-ventral line, the intervening wall thus formed breaks down so that the coelom extends completely around the developing gut. At the same
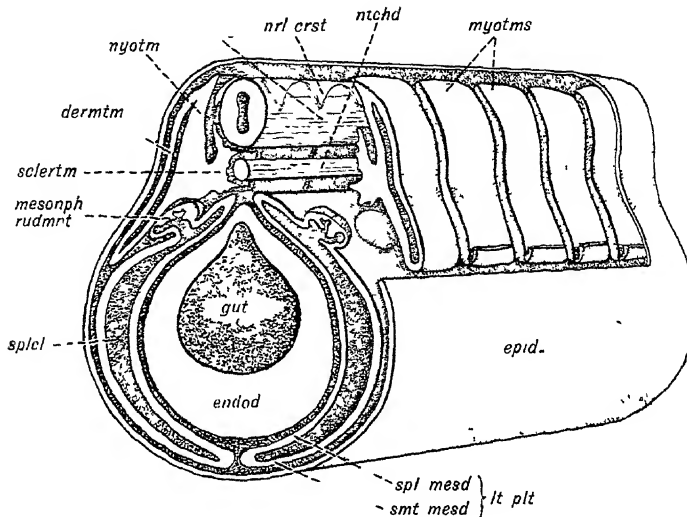

FIG 20 —Stereogram of a portion of the Trunk

In the second to the fifth somites shown, the dermatome has been cut away

c n s , central nervous system , *dermtm* , dermatome , *epid* , epidermis , *lt plt.*, lateral plate mesoderm , *mesonph rudmnt* , mesonephric rudiment , *myotm* , myotome , *nrl. crst* , neural crest , *ntchd* , notochord , *sclertm* , sclerotome , *smt mesd* , somatic mesoderm , *splcl* , splanchnocoel , *spl mesd* , splanchnic mesoderm.

time that these developments are taking place, the mesoderm is being further differentiated into its parts That lying on each side of the notochord forms the somite and is distinguished from the remainder—which forms the lateral plate mesoderm—by becoming metamerically segmented. Between the somite and the lateral plate mesoderm lies an intermediate region which forms the nephrotome and also exhibits metamerism.

Each somite make three contributions to future embryonic structures ; the myotome from which the body muscles are derived ; the dermatome, the mesodermal contribution to the skin ; and the sclero-

tome from which the axial skeleton is developed.   Within the somite and nephrotome, portions of the coelom are present forming the myocoel and nephrocoel respectively, whilst that contained by the somatic and splanchnic layers of the lateral plate mesoderm is the splanchnocoel which becomes the general body cavity.

Anteriorly, in the region of the pharynx, where the development of the somites is interfered with by the development of the sense capsules (particularly the auditory capsules) and visceral clefts, the coelom is restricted to a ventral portion which becomes modified and separated from the splanchnocoel to form the pericardial cavity.

THE COMPLETION OF THE GUT

In the description of gastrulation, it was emphasized that the invaginated endodermal presumptive area forms the walls of the
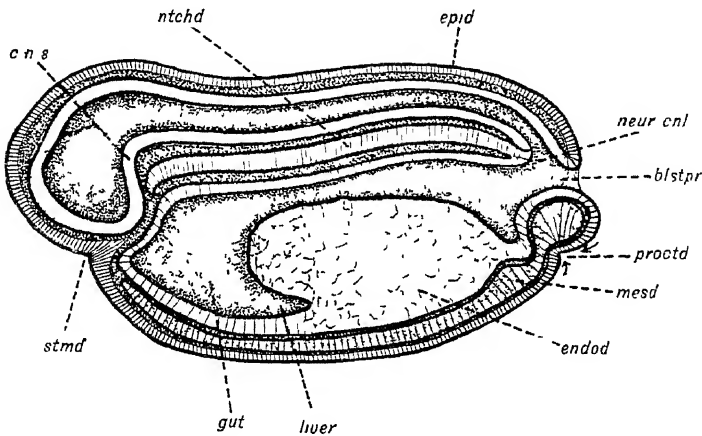

FIG 21 —Schematic sagittal half of a late Embryo

blstpr , blastopore , *c n s* , central nervous system , *endod* , endoderm , *epid* , epidermis ; *mesd* mesoderm , *neur cnl* , neurenteric canal , *ntchd* , notochord ; *proctd* , proctodeum ; *stmd* , stomodeum

archenteron with the exception of a narrow cleft immediately beneath the notochordal cells   The anterior and dorso-lateral walls are thin but the floor of the archenteron is occupied by the piled-up yolk-containing cells   At the time of the differentiation of the notochord, the upper edges of the endoderm meet and fuse in the mid-dorsal line so that the roof of the archenteron is completed.

Posteriorly, the blastopore was occluded by the yolk-plug but later this was withdrawn into the floor of the archenteron and the blastopore lost its circular shape, becoming elongated dorso-ventrally and, by the

meeting of the central portions of the lateral lips, 8-shaped.   It is the upper portion of this 8-shaped aperture which becomes enclosed by the fusion of the neural folds to form the neurenteric canal.   The lower part marks the position of a future invagination of the ectoderm to form the proctodeal involution which eventually establishes connection with the archenteric cavity.

Anteriorly, ventral to the front end of the neural tube, a similar inpushing of the ectoderm appears, giving rise to the stomodeum from which the buccal cavity will be developed.   It is from this stomodeal involution, in the region of the thalamencephalon of the fore-brain, that the hypophysis arises to contribute to the formation of the pituitary body.

Within the archenteron, just in front of the piled-up yolk-containing cells, a depression in the floor marks the appearance of the liver diverticulum.   Anterior to this depression lies the future pharyngeal region, in the walls of which the visceral clefts will develop.

(To be continued.)

SOME ASPECTS OF BIRD MIGRATION

By F. B. FIELD, M.A., B.Sc.
Ellesmere College

THE regularity of bird migration is commented upon in the world's oldest literature : Homer and Aristotle, Jeremiah and Solomon alike bear their testimony. But it has been a matter of speculation as well as observation, and some of the early ideas were highly fanciful. The crane, for example, was believed to carry the corncrake on its back. Morton, in 1703, wrote an essay to prove that swallows travelled to the Moon, and he calculated that the journey would occupy sixty days. At the conclusion of his essay he naively comments, " If the Moon be not allowed, some other place must be found."

For a long time it was believed that birds did not migrate, but hibernated, and there were many stories of swallows passing the winter in mud at the bottom of ponds and reviving in springtime. This was quoted in *The Natural History of Selborne*, but the great naturalist was obviously sceptical about it

Animal life began in the sea, in the shallow waters by the shore. During the course of evolution, primitive animals became more mobile and began to take to the land. It is quite likely that these creatures would return to their original element for breeding, and so we may feel some justification for considering that migration may be one of the most ancient characteristics of the animal world. Migration is practised at the present time by all kinds of vertebrates except mammals, though not, of course, by all species.

THEORIES OF MIGRATION

Reasonable theories were not forthcoming until Victorian times. Shifting food supplies were at one time thought to be the cause of migration. This may be an important factor for insectivorous birds, and it explains up to a point why birds go south in the autumn, but it does not account for their northward movement in spring, and this is the more regular and in some ways the more striking phase of migration.

Changes in temperature have also been regarded as the cause of migration, and it is true that birds rear their young more successfully in a temperate climate. But evidence shows that the effect of temperature is not more than a secondary factor A young bird only a few months old cannot know that the warm weather of summer will be followed by the rigours of winter any more than a young baby can, and it is sentimental rather than scientific to suppose that the bird flies south to escape the cold weather, as though it knew what was coming and how to avoid it In spite of this, considerations of food and temperature are commonly held to be the primary causes of migration, as an examination of " popular " books in any school library will show.

Another, rather grand, theory was advanced by Alfred Russell Wallace, the friend and co-pioneer of Darwin. He attributed migration to ingrained habits dating back to a glacial epoch, when the southerly advance of the ice-sheet forced the birds to retire from northern lands When the ice receded, the birds spontaneously went back to their old homes, and in this way the habit of alternating between the two regions came to be part of their nature. The disadvantage of this theory is that it is so difficult to prove either true or false. At best it is a somewhat subtle piece of scientific guesswork, a hypothesis which might find acceptance simply for lack of a better one

Migration is known to be an activity closely connected with breeding. Birds begin to migrate at a definite stage in the annual cycle of physiological changes occurring in the reproductive organs. Their periodic development is controlled by the annual increment of sunshine in springtime . Even within the British Isles we have evidence of this : for example, swallows in Scotland raise larger broods than swallows in southern England. A most important observation, by Rowan in Alberta ten years ago, was that migratory crows that lingered in winter had diseased gonads. The gonads are activated by sunlight, and as the length of the day increases in springtime the reproductive organs become more active, and in some way the bird receives an impulse to be on the move. Rowan followed up his observations with experiments on crows and also on juncos. He kept one group of juncos in captivity under natural conditions in autumn, and another group in cages which could be bathed in artificial sunshine. He found that the gonads of the second group remained in an active state, whereas in the control birds they diminished in size. And the juncos remained in full song when the temperature had fallen as low as $-44°$ F. Next he carried out parallel experiments with crows, and released them in

November, simultaneously broadcasting an invitation for reports on the movements of crows during the days following. The control birds which were shot down were, without exception, reported from places south of Alberta, while a large number of the experimental birds were shot down at places well to the north and up to three hundred miles away.

Briefly, then, the increasing daylight excites the reproductive system, and this manifests itself in an advance to the traditional breeding ground It is not a complete explanation, for although it tells us why the bird becomes more active, it does not account fully for the fact that the activity takes the form of migratory flight.

During the breeding season, the cock bird becomes very jealous of the territory selected as a breeding place, and, although the actual nursery is so small, the land around it for a considerable area is regarded as private, and a bird will fight to the death with any rival who dares to build a nest within range of his own. There may therefore be a problem of *Lebensraum*, and the urge to migrate may be due to competition for available space.

OBSERVATIONS AND DATA

The most comprehensive observations of migration are made on small islands Fair Isle, midway between Orkney and Shetland, although only three miles in length, is visited regularly by over half the species that come to this country. Heligoland is another excellent station, long famous for the pioneer work of Gatke. Skokholm, in the Bristol Channel, is another well-known haunt both of birds and of ornithologists.

The modern study of migration began in 1899 when Mortensen started a bird-marking scheme in Denmark. A small metal ring, which serves as a label, is placed on the bird's leg, and this can be returned to its station from the place where the migrant settles down. Millions of rings have been used, and although only a small proportion of them may be sent back, the statistics represent the movements quite reliably. In this country the work is supervised by the Bird Room of the British Museum. In the United States the " American Bird Banding Association " is a flourishing body.

NOCTURNAL FLIGHT

Most birds, especially the smaller perching birds, migrate at night. This explains why, although everyone knows about bird migration,

only a small proportion of people have ever observed it for themselves. More have seen swallows collecting in flocks, sitting on telegraph wires in the late afternoon. Birds fly during the hours of darkness for two reasons : first, for safety, and second, to ensure a plentiful food supply. Birds are voracious creatures, and they do not carry large reserves of fat which they could draw upon during long hours of flight. Therefore they fly by night and spend the daytime feeding and resting.

Nocturnal migration has often been described by astronomers when flocks of birds have flown across the face of the moon as they viewed it through their telescopes Pilots of aeroplanes often report meeting huge flocks of migrants, and some naturalists have described hearing the calls of migrant birds when it was too dark to see them. Light-house-keepers have plenty of evidence of the colossal scale of nocturnal migration Countless thousands of birds meet their death every year by dashing themselves against the lighthouse. Birds seem to come under a fatal fascination for the light and fly round and round until they fall exhausted into the sea. Eagle Clarke, one of the best known English Bird Watchers, making observations on the Kentish Knock Lightship in 1912, related how one particular kestrel careered round and round the light from 8 p.m. until 1 30 a m., rushing wildly towards the light and suddenly sheering away, over and over again. Mortality is particularly severe in foggy weather. At a number of lighthouses, perches have been provided by the Royal Society for the Protection of Birds, and this body has advocated a red light instead of a white one.

Altitude and Speed

Very few birds normally fly at heights above three thousand feet : most small birds remain within one thousand feet of ground level. Until scientific data were forthcoming, many birds were credited with flying at enormous heights, up to forty thousand feet. It was believed that at these great altitudes the birds gained by the lowered resistance of the air to their motion and became independent of the effects of contrary winds. But it is not difficult to think of biological objections to the idea, and the evidence of aeroplane pilots on this question is final.

Similarly, in the matter of speed, it used to be quite a vogue to believe the most extravagant estimates. Gatke claimed to have timed birds over a distance of about four miles in just under a minute. The

following are the generally accepted estimates of the speeds of a few typical birds :

Crows . . .	30–45 m.p h.
Geese	42–55 m.p h.
Small perchers . .	20–37 m.p.h
Swifts	50–70 m.p h

These are the normal speeds over hours of flight : they can maintain higher rates for short bursts. Birds can obviously cover distances of several hundred miles in a day, and it has been reported that birds captured in New York sometimes contain in their crops rice grains picked up at least seven hundred miles away.

Weather Conditions

Migration is not so dependent upon weather as we might suppose. It is true that birds do not set out on their long journeys if the weather is unfavourable, but if, after setting out, conditions deteriorate, the birds do not interrupt their flight. Sometimes they run into very bad weather and thousands of birds may perish in a bad storm, but they will fly on until they are exhausted. Fog confuses their " sense of direction," strong headwinds cause delay and fatigue, but perhaps snow is their worst enemy. A tragic report came from U.S.A. in 1907. Flocks of birds flying over the lakes of Minnesota ran into a bad blizzard, and a few days later the bodies of hundreds of thousands of dead birds were found on the ice. The migrants had lost their " sense of direction," struck the ground in full flight and had been stunned to death.

Ordinary variations of weather have little effect, though many birds have a marked preference for taking to the air during anti-cyclones. It is a popular belief that if summer migrants leave the country earlier than usual, a hard winter is sure to follow. There may appear to be a little foundation for this idea, but it is difficult to believe that birds have the sagacity to predict the weather two or three months in advance. This is little more than an old superstition, widely believed because it is occasionally, and accidentally, true.

The Journey

The distances covered by some birds are enormous : the Arctic Tern holds the record. This bird nests within five hundred miles of

the North Pole and winters on the Antarctic Continent, eleven thousand miles away. The Arctic Tern must enjoy more sunshine than any other living creature, spending its time as it does in the perpetual daylight of polar summers.

The Golden American Plover breeds along the Arctic shore of Canada and spends the winter months in the Argentine. It is peculiar that this bird does not use the same routes on its outward and return journeys. In autumn it follows the Atlantic coast of Labrador and Nova Scotia and then crosses the ocean, via Bermuda, to the South American continent. Next spring it returns over the Central American isthmus, crosses the Gulf of Texas and flies up the Mississippi valley and over the mainland to its breeding ground

Some of our own migrants undertake very lengthy journeys : swallows and wagtails are among those that go to South Africa. Crossing two thousand miles of ocean, as the Golden American Plover does, is a remarkable feat, but perhaps it is even more strange that a water-loving bird like the Wagtail should successfully fly across the Sahara without a single halt. Over seventy European visitors are known to winter regularly at the Cape, including the Stork, which has recently been used by the Dutch for sending uncensored messages out of Nazi-occupied Holland.

How do birds find their way ? Do they recognize landmarks : mountains, rivers, islands and capes ? There is a good deal of evidence that they do. For example, birds are known to congregate on lonely islands, but, on the other hand, they regularly fly across the ocean and the fact of nocturnal migration raises further difficulties. The way in which a bird will leave its summer home and fly south, and come back next year to the identical spot is most uncanny, but there are plenty of authentic cases of their doing so. A young cuckoo flying south on its first migratory journey cannot recognize the way because it has never made the trip before. Furthermore, it is not accompanied by its parents, for the older birds move south several weeks before the young ones

An Unsolved Problem

We do not really understand how birds come to undertake these flights, and we have very little idea how they find their way. There must be some kind of mechanism setting them off, some kind of mechanism guiding them on their journey. Experiments were being carried out in Poland to test a suggestion that terrestrial magnetism

might play a part in north and south migration, but these were interrupted by events in September, 1939.

We may well believe that a bird enjoys flight : it looks an eminently pleasurable and exhilarating experience. But it is also an arduous business and proves fatal to large numbers of birds. Indeed, migration is one of the means by which the less hardy individuals in a flock are weeded out and a premium placed upon survival value, towards which the " Migratory Instinct " makes an important contribution.

It is a commonplace to say that birds and other animals possess a sense of direction far more acute than our own. This is merely stating the problem of migration in different terms, and it is in no sense an explanation. There is something fundamentally astonishing in the simple fact that the single fertilized germ-cell of an embryo contains within itself the means by which its later division and differentiation is controlled. The primary embryonic cell of any animal develops naturally into the mature specimen of the species. Cats do not have puppies, neither do dogs have kittens. The young fledgling emerging from the shell is equipped, not only with the same physical paraphernalia as its parents, but also with the same traditional habits of correct behaviour. It knows how to build its nest : it knows what kind of food to look for : it does not require to be taught the technique of mating, and it possesses the secrets, unknown to us, of migration. Secrets they will remain until we have a much more accurate insight into animal instincts altogether. In fact, the birds will have to be psycho-analysed.

For further reading :
Birds as Animals : James Fisher. (Heinemann)
Birds of Great Britain W. P Pycraft (Williams & Norgate.)
Migration of Birds : Wetmore. (Harvard.)
Personality of Animals : H. Munro Fox. (Pelican Book.)
The Countryman, numerous references.

THE ANIMAL AND ITS ENVIRONMENT

By H. N. SOUTHERN, M.A , F Z S.
Bureau of Animal Population, University of Oxford

1. THE ANIMAL AS A SYSTEM

AMONG the older school of morphologists there was a tendency, perhaps unconscious, to regard animals as " things in themselves," to use Aristotle's phrase, and to study them as objects, more often dead, without relation to their environment.   The attentions of physiologists and ecologists now emphasize the ultimate interdependence of all matter, living or dead.   As Elton [1] has said, animals may more truly be regarded as little bits of the environment temporarily formed into systems and through which energy continues to flow.   It is the direction of this flow which is organized to form the animal and not just a static agglomeration of formal materials   It is ultimately as impossible to think of an animal without its environment as to think of oneself without things to think about.

The sum of processes known as an animal's metabolism, by which dynamic equilibrium with the environment is maintained, is governed by the same physical laws as the relations between inanimate objects, and this leads us to the concept of the whole material world being mutually interdependent, every process that takes place being ultimately expressible as an equation, if only we knew the terms.   Of course, they are too complicated for us ever to know them in their entirety, but we are able to make abstractions which are perfectly valid for the progress of scientific thought.   The nitrogen cycle is an example : the idea is of a gigantic background perpetually in movement according to physical laws, and against this animals appear as foci causing a temporary canalizing of this movement, but in no way altering its real nature.

Of course, there are inanimate systems which focus energy in certain ways, but as soon as life appears, there is a new feature involved, and it is this element which is of importance here.   The system which an animal forms is in physical terms, as Young [2] has pointed out,

an " improbable " system, and the more advanced the animal, the more " improbable " is the system it constitutes. We may now speak of an animal " using " its environment inasmuch as it directs to some degree the change that is going on. The degree of use dictates the place which the animal will occupy ecologically and how it will be related to others in the hierarchy of animal relationships ; also in another dimension how it is related to its ancestors ; in other words, how it has evolved.

These two aspects therefore are the most striking and important in a study of the relationship between an animal and its environment : *the way in which an organism maintains its character and continuity* in the face of the disintegrative effect of environmental forces, and *the way in which an organism varies*, so as to make evolution possible.

2. THE CONSTANCY OF ORGANISMS

This first aspect, the constancy of an organism, is what the taxonomist is expressing in his classifications. The concept of the species as the main taxonomic unit is a perfectly valid one for many reasons, which cannot be gone into here. Chief of these, however, is the bar to interbreeding, once the hereditary factors become too unadjusted to pair. The behaviour of the chromosomes therefore constitutes one of the main factors preserving the stability of an organism, but the same mechanism also provides a way of ensuring variability within safe limits.

If an organism starts out upon life at the moment of fertilization with the datum, as it were, of its hereditary constitution, it follows that slight movements in one way and another in the equilibrium between it and its environment will produce variable phenotypic effects. A given factor will produce different effects according to the conditions to which it is subjected. This is shown in the common effect of rate genes, affecting, for example, the speed of deposition of melanin in the eye of *Gammarus* or the speed of sexual differentiation in *Lymantria*.

3. GENIC INTERACTION

Before discussing more broadly the interaction of organisms with their external environment, it is necessary to be quite clear about the process of genic interaction. In so far as a character may be modified by the presence of a genetic factor, or factors, other than the one most directly responsible for it, every character is affected by all the

genes, so that in one sense a gene is as much a unit without meaning as a wheel out of a clock   If this is so, a factor will react within its *internal environment*, i.e., the rest of the gene complex, and demonstrations of this fact are not wanting.   Among many other examples, the most important is the decrease in viability of an organism into which a mutant gene is introduced.   The gene complex is unadjusted, but if the stock is inbred for several generations, sufficient recombination will take place for the mutant gene to find itself in different internal environments.   Selection will naturally act to preserve those in which the least decrease in viability is exhibited, which has obvious evolutionary implications   However, the point to make is that a particular character will vary not only according to the physical or biotic factors influencing it from without, but also *ab initio* according to the genetic constitution from which it springs.

The phenomenon of crossing over, also, exerts a most important influence on evolutionary progress, as upon specific stability.   Darlington [3] has shown that this is of almost universal occurrence and its purpose is to ensure regular pairing of the chromosomes (in male Drosophila chiasma formation takes place without crossing over), and also to break down the effects of linkage, which curtails the amount of possible recombination.   Crossing over is mentioned further below.

4. THE EXTERNAL ENVIRONMENT.   LIMITING FACTORS

When we turn to the external environment, we find that although its effects are obvious, nevertheless, they are very difficult to analyse with any completeness.   The whole subject of ecology deals with this, and although it is often clear that such and such adaptations fit an animal for such and such a niche in a community, it is not always clear what are the limiting factors which prevent its straying even a little way out of such a niche

The crux is to narrow down the limiting factors ;   clearly, in a broad way, life is limited by upper and lower thresholds of certain factors.   A certain amount of water must be present, a deficit necessitating disproportionately elaborate adaptations, such as diapause in insects and aestivation in vertebrates ;   a narrow range of temperature must be preserved, since the complex protein molecules of protoplasm can withstand neither freezing nor an excessive rate of metabolism, which breaks them down ;   light, food supply, oxygen, etc., must all be available in appropriate quantities.

5. "INDEPENDENCE" OF THE ENVIRONMENT

Within these limits, therefore, life is possible, though naturally an optimum is sought at which the animal may be most efficient. This efficiency consists in maintaining the unity of organization in the face of the constant flux of energy passing between the animal and its environment. Thus we must beware of regarding " lower " organisms as in any way less efficient than " higher " ones, since they maintain and reproduce themselves equally well. However, the terms must obviously have important meaning, and the relationship between animal and environment is nowhere more clearly traced than in the progress towards greater use of the environment shown in higher animals.

Such progress is well illustrated by the evolution of the nervous system (Young, *loc. cit.*), for this is one of the most obvious criteria by which the degree to which an animal is *en rapport* with its environment can be judged. In many lower organisms, the tissue fluids have an ionic composition almost the same as the medium in which they live. It would be superfluous for them to have elaborate means of being informed of small changes in their surroundings, since they need not be continually making adjustments to preserve their organization. However, as soon as dry land was colonized, a far more complicated relation came into existence between organism and environment, which probably accounts for the fact that no such colonization occurred until fairly late in geological history, when animals had already attained a high degree of organization. Not only must the basic physiological adjustments be made to prevent drying up, collapsing, or suffering from osmotic disturbances, but finer detail in " manipulating " the environment is necessary.

The simple arrangement of receptor-connector-effector becomes elaborated in all its aspects.

(1) Receptors become able not only to detect smaller changes in stimulation, but quite new imports : auditory receptors register not merely changes in pressure, but respond differentially to sound waves and even to patterns in sound ; similarly with vision and chemical senses. Not only are there more receptors to each kind of stimulation, but many kinds of receptor are concerned in one effect.

(2) Effectors, which originally moved the whole animal, become specialized for making more finely adjusted movements, and the complex musculature of insects and vertebrates contrasts with the simpler type of, for example, an annelid.

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(3) The development of the connector system, the central nervous system proper, is the greatest advance. In this way integration is made possible and new kinds of responses appear, which are not the result of a number of discrete stimuli, but a reaction to a situation as a whole.

Still further an elaboration is that of conscious or directed action, where previous experience is invoked in modifying behaviour   In man, the control of the environment appears in the highest degree, though the basic restrictions still operate.

6. THE EXTERNAL ENVIRONMENT.   PHYSICAL FACTORS

Having realized, therefore, the varying degrees of influence which organisms may have upon the environment, as one goes up the scale of the animal kingdom, it will be profitable to survey the various factors, which constitute the external environment, in more detail. The discussion must of necessity be scrappy, since it must waver between giving examples and showing principles at work.   This may emphasize the complexity of the subject.

In addition, it should be remembered that to abstract any of these factors and consider it alone is only a convenience and in reality all other possible factors, which compose the complex of the environment, must equally be taken into account.   Thus the perfectly controlled experiment is a thing difficult to achieve.   Even when the main factors, light, temperature and humidity, have been correctly evaluated, there are others which exert an effect, such as pressure, which has considerable importance among other things on gaseous exchange in respiration, movements of the medium, for example, air currents and flow of water, oxygen tension and generally the gaseous composition of the medium, and the hydrogen ion concentration, which has sometimes very marked limiting effects upon an animal's distribution.   These few examples help to show how difficult is the ecologist's or physiologist's task, when he sets himself to analyse an animal's environment.   For a further discussion of this aspect of the subject the reader may be referred to Chapman [4].

Of the basic limiting factors before mentioned, temperature is of the utmost importance.   The methods adopted by animals for seeking out and preserving an optimum temperature environment are varied in the extreme, as are also the physiological adaptations to this end. Most of the lower organisms are at a disadvantage in that they have

no means of creating an environment of their own and must function at the temperature of surrounding conditions. " Seeking " is executed by simple tropisms : the avoiding reaction of, for example, *Paramecium* almost achieves the required result by simple trial and error. As we ascend the vertebrate scale, however, homoiothermy becomes more effectively developed, until in birds and mammals we find the highest degree of use of the environment. Here the temperature of the organism is regulated to a more or less constant level, and it is achieved more by heat loss than by heat production. This is well shown by the difference between any eutherian mammal, where the respiratory rate increases with an increase in temperature, so that more heat is lost *via* the lungs, and a primitive form like *Echidna*, where the respiratory rate decreases, until suffocation supervenes (see Borradaile [5]).

The advantages of homoiothermy are well illustrated by some of the facts of geographical distribution. The tropics show an immense abundance of poikilothermous animals, but these peter out northwards and southwards towards the poles, whereas " warm-blooded " animals are equally represented all over the world. In high north latitudes the land fauna is mainly composed of mammals and birds. The insects are an apparent exception to this, but they have achieved a wide range of tolerance only by the most far-reaching adaptations entailing a long resting period. It is noticeable that the vast majority of Arctic and Antarctic birds and mammals live on marine organisms, for in the sea there is far more homogeneity of population from north to south, since among other reasons there is a less wide range of temperatures. It should be remarked, however, that homoiothermic animals may only be adapted to a small range of temperatures : the Alaskan fur-seal suffers great discomfort if the temperature rises much above 40° F. (see Elliott [6]).

Nowhere is the control of the environment more clearly demonstrated than in the migrations of birds. These vary in degree, but in the most extreme cases, such as the curlew sandpiper (*Calidris testacea*) and the Arctic tern (*Sterna macrura*), journeys totalling between 10,000 and 20,000 miles a year may be made to ensure breeding in optimum conditions.

An aspect of the temperature factor in the environment, which is connected with the migratory habit, is the occurrence of rhythms in temperature variation. These are of course chiefly diurnal and annual and to them animals become adjusted physiologically. The effect of the diurnal rhythm on the life of most animals is obvious, yet it is

interesting to find that even in the Arctic, where there is continuous daylight in the spring, this rhythm persists, and from about 11 p.m. to about 2 a.m. song and general activity cease.

Breeding rhythms are undoubtedly broadly connected with temperature, though it is so fashionable nowadays to work upon light as a factor which stimulates breeding that other equally essential aspects have suffered neglect. Many marine organisms are dependent upon temperature for their breeding rhythm (see Orton [7]), and this applies equally to many land animals. The interaction between the metabolism of insects and effective temperature exhibits so constant a relationship that it can be formulated as the temperature-sum rule (see Bodenheimer [8]). Thus longevity in insects is a function of effective temperature ; if the latter rises, life is shortened, and if it falls, life is extended. This applies particularly to the embryonic period.

So markedly do insects show themselves to be dependent upon environmental conditions that Bodenheimer has applied a series of indices, whose value expresses the effect of each environmental factor upon an insect's longevity or " success ", to estimating the degree to which that insect will flourish in any given circumstances. The sum of these is known as the " bonitation index."

However, if breeding rhythms in higher animals are ultimately controlled by physical factors, as with insects, the relationships are much more obscure and many intermediate factors are interpolated. Baker [9] and other authors have rightly insisted that, although the ultimate cause of breeding may be the coincidence of environmental circumstances favourable to the upbringing of the young, proximate causes and the mechanisms through which they work may be extremely varied. Naturally, in poikilothermic animals, temperature puts a check on breeding by stopping activity when it passes below a certain threshold ; in warm-blooded animals there are more complications. A long period of gestation may mean that sexual activity must take place in extreme cold for the young to be born in favourable climatic conditions. Thus internal rhythms may be developed, which may act in co-ordination with external stimuli, or may merely be " kept on the rails " by them. The endocrine system in many vertebrates has been shown to control breeding and to act as a mediator between changes in the gonads and in the external environment (see Rowan [10], Bissonnette [11], Marshall [12], etc.).

Leaving rhythms, we may now briefly consider geographical varia-

tion in connection with environmental factors. It becomes difficult here to treat temperature by itself, so other elements will come in with it. The whole question of plans or schemes underlying such variation has been treated well by Rensch [13], who points out that both Arten-kreise, or systems of species composing a genus, and Formenkreise, or systems of forms composing a species, are the result of a dynamic interaction between the power of expansion of a species or genus and the modifying effect of the environment. Certain special tendencies are observable again and again : there is, for example, Bergmann's Law, which states that of nearly related warm-blooded animals the larger occupy the more northerly districts (for example, European wrens of the genus Troglodytes). This is probably a temperature effect, since greater bulk means less relative surface area. Allen's Law states that the extremities of mammals living in high latitudes are smaller than those living nearer the equator, and Gloger's Law remarks the greater tendency to paleness and greyness of northern mammals and birds. This last may be a humidity effect.

Innumerable examples of such geographically " patterned " variation could be given, and these are not always simple trends from north to south and east to west, as in the willow tits (*Parus atricapillus*), quoted by Rensch. The races of blue-headed wagtail (*Motacilla flava*) show a central stock of the type in central Europe with various races radiating off and varying in different characters. Northwards and southwards are darker races (*M.f. thunbergi* and *M f. cinereocapilla*), eastwards is a paler one (*M f. beema*), and westwards a yellower one (*M.f. rau*). Such gradients may also exist in the proportion of polymorphs (see Southern [14]).

Huxley [15] has pointed out more precisely the nature of these geographical gradients and has suggested that the more detailed description of these clines—to use his term—would be of great use to the normal taxonomic procedure.

A word must be said about variation and the environment from the genetic side. In optimum conditions, the cross-over value between two factors is usually fairly small, but as soon as, for example, temperature falls below, or rises above, this optimum, cross-over values increase greatly. This is very significant and shows one way by which variability may be increased, when conditions are not ideal. Among the recombinations thus produced, some may be more adapted to live under the new circumstances. It is noticeable that in a stock of *Paramecium*, ordinary fission will go on almost indefinitely while

conditions are good, but as soon as any unfavourable factor appears conjugation takes place.

A great deal more might be said about the relations existing between animals and particular environmental factors. Much work has been done recently illustrating the importance of light in controlling the breeding seasons of animals. The stimulus acts by the mediation of the pituitary and for some species a cycle in cellular activity has been traced in this gland. The migration of plankton is another noteworthy instance of the effect of light.

Humidity is of great importance in many cases, and the peculiar characters of desert faunas (see Buxton [16]), both physiological and morphological, show how many are the ways in which an animal may avoid drying up. Other effects are seen in, for example, wet and dry season forms of some Lepidoptera (see Poulton [17]) and in many cases breeding seasons in the tropics may be controlled by the incidence of the rains. Other factors of the medium in which animals live exert their effect—exposure, wind force and direction, pH of the soil and (in aquatic communities) salinity, wave-action, type of substratum, etc.

As a final note on the physical factors of an animal's environment, we may consider briefly some of the less obvious changes necessary for an animal to progress from a marine to a fresh-water and then to a land habitat—the most important evolutionary steps that were taken —and the degree to which these changes implied increasing independence of the environment. In many forms of marine invertebrates, the tissue fluids have roughly the same ionic composition as the surrounding medium, so that no osmotic upsets are likely. A change into fresh water implies some method of preventing the ions in the blood from escaping by osmotic pressure. This is achieved by preventing exchange in all but a small area of the body—hence gills— and making this region impermeable to salts. A hypotonic urine is excreted to carry away the water that is constantly entering. This change also implies an intermediate condition in which the animal is able to exist in a wide range of salinity conditions. The change to dry land is even more complicated, because of the necessity for preserving surfaces for exchange and yet keeping them moist. The surface membrane of lungs has to be thicker than that of gills on this account and exchange is not so efficient. Even greater difficulties are associated with reproduction, and the evolution of the embryonic membranes alone have made it possible to cut out the links binding an animal to an aquatic life. The whole subject is excellently reviewed

by Baldwin [18]. However, once achieved, these adaptations have made it possible for almost any environment in the world to be occupied.

7. THE EXTERNAL ENVIRONMENT. BIOTIC FACTORS

The other large class of factors with which an animal comes into contact are the biotic ones, i.e., surrounding forms of life, whether plant or animal. It is not proposed here to deal with the general principles of animal ecology, which have been well expounded by, for example, Elton, Chapman (*op. cit.*), but to touch on one or two aspects of the relationships existing between animals living in the same community.

In the first place, there are what may be called destructive relationships, such as that between predator and prey. Many biologists do not realize, and indeed it calls for a great effort of the imagination, the amount of destruction that does go on. Darwin [19] with characteristic insight realized it and also realized the vast nexus of such relationships, which thread their way through an animal community. His concept of the struggle for existence may involve something metaphorical, as he himself admitted, but the situation cannot be expressed better. In this matter also increasing independence of the environment is observed, as we go up the scale of the animal kingdom, inasmuch as increasing care of the young means producing less, so that a vast surplus is not needed to ensure the survival of one or two.

Even with slowly reproducing animals, however, the potential rate of increase is very high. Both Darwin, in more simple language, and modern biomathematicians have shown that populations increase at the beginning exponentially and that the asymptote of the logistic curve, which expresses the normal (as apart from the potential) growth of a population, owes its character to biotic factors (see Pearl [20]).

Modern students of the balance and fluctuation of animal populations are divided between attributing population control to density dependent factors, for example, predatism (Nicholson [21]), and to such relatively stable factors as climate (Bodenheimer, *op. cit.*), but it seems difficult to discriminate in such a case.

Naturally, as Darwin saw, competition for food supply will be a potent limiting factor to population increase and particularly so between members of the same species. Many adaptations in behaviour spring from this, one of the most interesting of which is the system of occupying territories seen in many vertebrates and particularly in birds.

The work of Eliot Howard [22] in particular has shown the indispensability of territory possession in some species for successful reproduction. Males without such dominions simply do not get mates and are thus eliminated. Linked with this is the whole important question of aggression in colouring and behaviour, which gives an advertising advantage to an animal in competition with others. Mullerian mimicry in Lepidoptera and other groups (Hale-Carpenter and Ford [23]) is one example of this use, while the subject is reviewed at some length by Hingston [24].

In opposition to all this there are constructive relationships between animals. Flocking and social life generally represent the appearance of a higher unit than the individual, thus increasing the chances of race survival. This is even shown to apply to birds, whose nesting colonies have the appearance of mere social gatherings, but in reality are necessary to the successful carrying out of the reproductive function (Fraser Darling [25]).

Among the most remarkable of such relationships is that of symbiosis. There are many degrees of this, varying from commensalism, where two animals of different species derive a common advantage from a close association, to symbiosis proper, where the one cannot live without the other, as in the case of the flat worn *Convoluta* and its symbiotic algae.

Parasitism is not quite a constructive relationship except for the parasite, and yet it is not wholly destructive of the host, for this would defeat the parasite's own ends. Nevertheless, it really represents a special aspect of the predator-prey relationship.

Finally, a most interesting direct physiological affect of association may be mentioned. In locusts, the close contact of numbers of hoppers actually affects the animals' metabolism, so that a new phase appears, distinguished both morphologically and by behaviour, for it is migratory and forms into the swarms of flying adults that are so proverbially vast and destructive. This change seems to come about in no other way than by the heightened activity caused by close association (see Uvarov [26]).

8. CONCLUSION

Such, roughly, are some of the physical and biotic factors which enter into the complex, which we call an animal's environment. It has been impossible to speak of them as if they were not in some way separate from and outside of the animal, but fundamentally such an

outlook is fallacious, as explained earlier. So long as the full complication of the situation is realized, investigation and discussion of abstracted elements are of value. This is, in fact, the only way of tackling any problem, but the necessary premise must not be overlooked.

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NOTE ON THE POLLINATION OF AUCUBA JAPONICA, THUN. (THE SPOTTED LAUREL)

By E M. DELF, D.Sc Lond.[1]

AUCUBA JAPONICA, Thun , the spotted laurel, is a dioecious plant frequently to be found in shrubberies and gardens. The flowers are erect upon a rather stiffly upstanding raceme with somewhat distant internodes. Both male and female flowers are inconspicuous, but at the top of the inferior ovary there is a fleshy disk which secretes nectar plentifully for several days when the weather is not too dry.

Early in June, 1941, I was asked by a teacher of Science of much experience how pollination occurred (if it occurred) in *Aucuba*, as she had been unable to find any reference to the plant in Knuth's *Handbook of Flower Pollination*, a work of encyclopædic proportions. I could not give any very definite answer, though I recalled that bushes in the garden of Westfield College (Hampstead) were freely visited during flowering by many (unidentified) black flies. The female plants there usually fruited abundantly.

The flowering period of *Aucuba* in the Botanic Gardens at Oxford was not yet ended, when, a few days later, an opportunity arose for an investigation into the matter. This was made jointly by four students, J. Cooke, J. M. Millard, E. Griffiths and M. Spoor, taking Honours courses in Botany for the London B.Sc. degree. Observations in the open were followed by a study of the pollen found in the anther and on the insects.

The morning chosen was sunny with cloudy intervals, rain having fallen previously. The disks of even old flowers glistened with nectar. Five bushes were observed ; two females in the same bed well separated py a number of trees and shrubs, the latter including a small male bush as well. This bed adjoined a lily pond. Two other plants of opposite sex were also observed. These were about 100 yards from the others, separated from them and from each other by the building

of the Herbarium.   The female plants were all bearing numerous ripe berries as well as flowers.

The bushes were haunted by numerous insects.   Small ones predominated, but much larger black flies were also flying around, although these were not seen actually visiting the flowers.   The small insects (resembling midges) were seen resting on the foliage, flying among the leaves and visiting the flowers.   A number were caught in wide-mouthed bottles containing chloroform vapour.   Insects from the male and female plants were kept in separate bottles ;   both proved on

Pollen grain   B

A

C
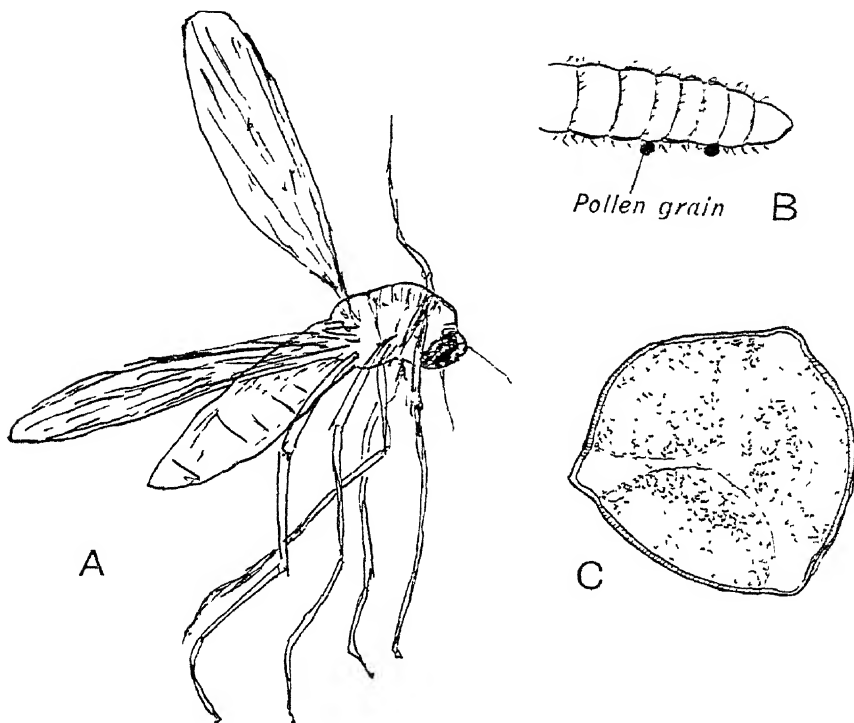
examination to have pollen grains among the bristles on legs, wings, antennæ and abdomen.   One insect (collected by E. Griffiths) had a whole anther attached to it.

After some difficulty, grains from the insects were isolated and measured.   Pollen was also collected from anthers of male flowers and was found to compare closely in form and size with that on the flies.   The characteristic triradiate grooves and the finely granular appearance are shown in Fig. 1C.   The same type of pollen was finally found on the stigmas of female plants, some of the grains having germinated.

Some of the insects were submitted for identification to Dr. B M. Hobby of the Department of Entomology, Oxford University Museum. He kindly informed us that the insects included various species of the Chironomidæ (midges); that they had aquatic larvæ and probably bred in the adjoining pond. Subsequently he sent five specimens to Mr. H. Britten of Manchester, who determined them as—

Culicidæ :	*Chaoborus crystallinus* Deg.
Chironomidæ :	*Cricotopus tibialis* Mg.
	Chironomus pedellus Deg.
	., *sp. indet.*
	Tanytarsus eminulus Walk.

Of these, apparently *Cricotopus tibialis* has not previously been recorded from Oxfordshire.

The figures were made from drawings made by J. Cooke under ordinary class conditions and do not pretend to exactness of proportion or detail. Fig. IA gives quite a good idea of the general aspect of one of the insects (female, probably a *Tanytarsus*). The pollen grains were observed and drawn under the high power (one-sixth) of an ordinary student's microscope. It is a pleasure to add that the observations and drawings owe much to the help and stimulation of Dr. Mary Calder, who has recently become a lecturer at the college.

From the observations recorded there can be no doubt that (1) midges are attracted by both male and female flowers of *Aucuba*, (2) pollen grains and even anthers are carried on the bodies of the insects, which fly from one plant to another.

It is notable that no other kind of pollen was found on the insects, although the small flowers of *Ruscus aculeatus* were open on closely adjoining plants. No other insects were seen actually to visit the flowers of *Aucuba*, although observations were made on several occasions to determine this; moreover, when a few days later all the flowers had withered, no more midges were seen around the bushes. It seems therefore that the midges were here the effective pollinating agents. It is not suggested, nor indeed likely, that the midges are the *only* effective agents. The nectar is so exposed and so abundant as to be obviously accessible and attractive to any short-tongued insect, and it is hoped that further observations may be possible next summer, beginning earlier in the flowering season.

It may be of interest to add that shortly after the withering of the flowers all the ripe berries had disappeared.

Apparatus for Determination of Back E.M.F. of Electrolytes (W H Dowland and N Herbert)

Large platinum electrodes are used, and are held rigid by warming them and then sticking them on to glass plates covered with molten paraffin wax : pressure between thumb and finger will ensure good contact all over the glass plate, and the foil is held flat when the wax cools.

If the plates are immersed parallel and vertical in a beaker ¼ full of molten wax, which is then allowed to set, they will be held rigid, and experimental liquids can then be poured in on top of the wax . most liquids used in simple conductometry do not attack wax. Terminals of the Daniell cell type may be used to make contact with the platinum foil.

The usual type of platinum electrode, consisting of a piece of foil welded to a short piece of wire, is very easily broken or deformed, whereas

Platinum foil on glass plate

Electrolyte

Paraffin wax

V

A

Cell

Variable resistance
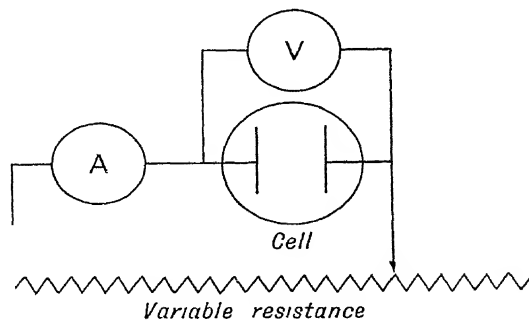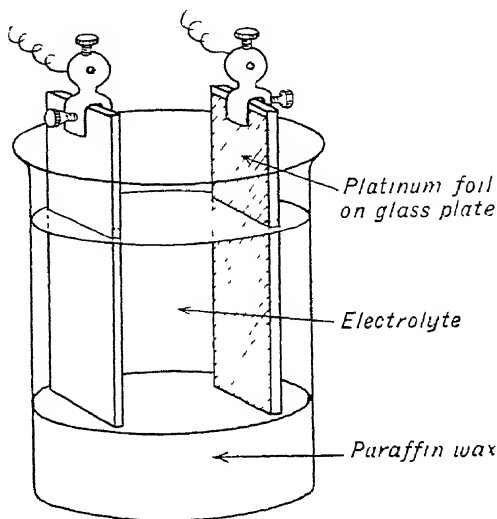
Accumulators

rigid ones made as described can be used over and over again without any trouble. Moreover, this type of cell has the further advantage of being very easy to fill and clean.

With bright platinum electrodes, and ordinary bench dilute sulphuric acid, the back E M.F. is about 2 2 volts. If the electrodes are platinum blacked (by electrolysing a 2 per cent. solution of platinic chloride with a little added lead acetate or formic acid, the current being reversed every half-minute for about ten minutes) this back E.M.F. is reduced to about 1·8 volts.
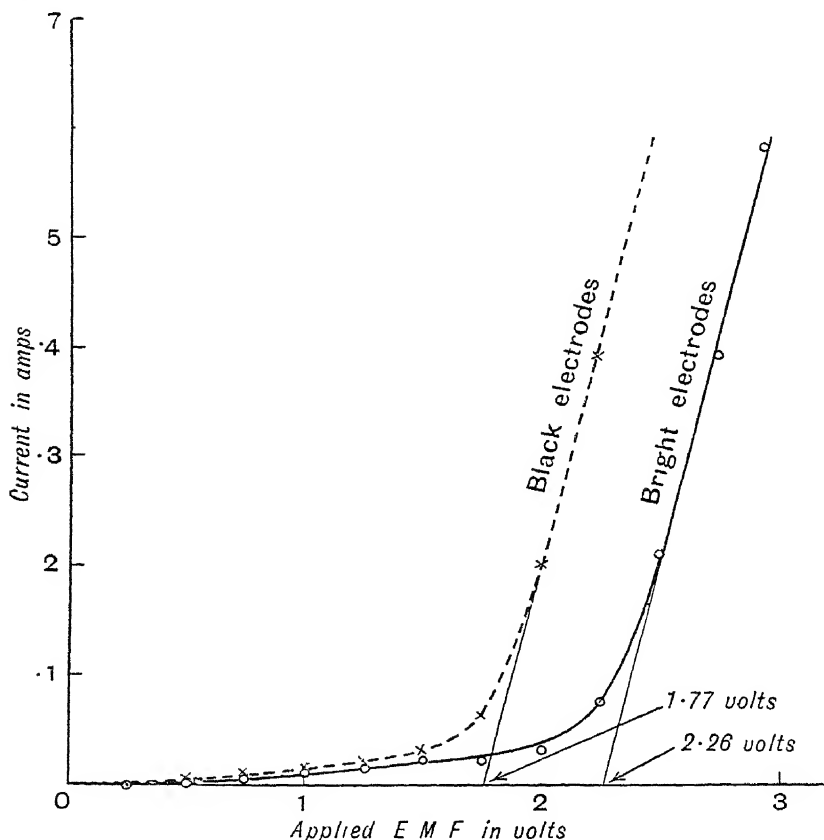
The voltage applied to the cell is conveniently varied in steps of 0 25 volt, as registered on a 3-volt voltmeter of resistance about 100 ohms, and the current is recorded on a 1-amp ammeter. A Zenith variable resistance, with a maximum of about 12 ohms, is used as a potential divider

Charles's Law Apparatus (W. H. Dowland)

A common form of apparatus for proving Charles's law consists of a length of capillary tubing with a column of air imprisoned in it by concentrated sulphuric acid. It is worth while to seal a glass stopcock on to the open end of the tubing ; the sulphuric acid need not then be renewed from year to year because of absorption of moisture. To attempt to put rubber tubing and a glass stopper over the open end usually breaks up the acid thread.

To remove Thermometers, etc., stuck in Rubber Corks (W H Dowland)

Select a corkborer which will just fit over the thermometer · push it through the cork with a rotary motion in the usual way, and the thermometer will drop

out.   The cork is either not damaged or little damaged ; and if it is damaged, the cost of a new one is less than that of a new thermometer.

Kathode Ray Oscillograph as Null Instrument for A.C. Bridges (W. H. Dowland)

The oscillograph, with the amplifier control at maximum, and the time base giving a horizontal line on the screen, can be used as a null instrument for detecting the point of balance in Wheatstone bridge work with alternating current, e g , for resistance of electrolytes, comparison of capacities by de Sauty's method, etc.   The bridge is fed with 2 volts A.C. from a transformer, and balance is indicated when the A C wave trace flattens out into a straight line

The Vibrations of Stretched Strings (W E. Pearce)

The following are suggested as suitable demonstration experiments for middle school work   The apparatus used is shown in the figure.   The crank AC is made by bending a piece of iron of length 18 in. and diameter $\frac{1}{4}$ in.   The " throw " of the crank should be $\frac{1}{4}$ in. or less.   One end of it rests in a bearing E which can be made by boring a $\frac{5}{16}$-in hole in a block of wood   The other end is connected to the shaft of a high-speed motor ($\frac{1}{10}$ h p) by a short strong piece of rubber tubing   A and C are two loose clips placed over the crank.   They can be made by bending short lengths of strip iron as at (a), or a small paper clip can be used.   Strings AB and CD of length 10 ft or more are fastened to the clips and to holes bored in a 12-inch rule.   It is convenient to make BD equal to 10 in   The ruler can be pulled to the left by a string attached to the ring F and so various tensions established in the strings. For the purposes of the experiment it is not necessary to know the actual tensions set up, but the position of the ring F determines the ratio of

(a)

the forces in the two strings, i e. if BF = FD the tensions are equal but if BF = 2FD the tension in DC is twice that in BA.   To show that the wavelength varies as $\sqrt{F}$ if n is constant, two identical strings are used and the pull first applied at the mid-point of BD.   The motor is started and transverse waves are sent along the two strings.   The tension is adjusted until the strings vibrate in one, two or more loops.   Since the tension is the same in both strings the number of loops in each will be the same   The ring is then moved so that DF = 4FB and the tension in AB will be four times that in CD.   A pull on F which causes AB to vibrate in one loop will cause DC to vibrate in two loops.   Again when DF = 9FB a single loop in AB corresponds with three loops in CD.

To show the variation produced by using strings of different linear density
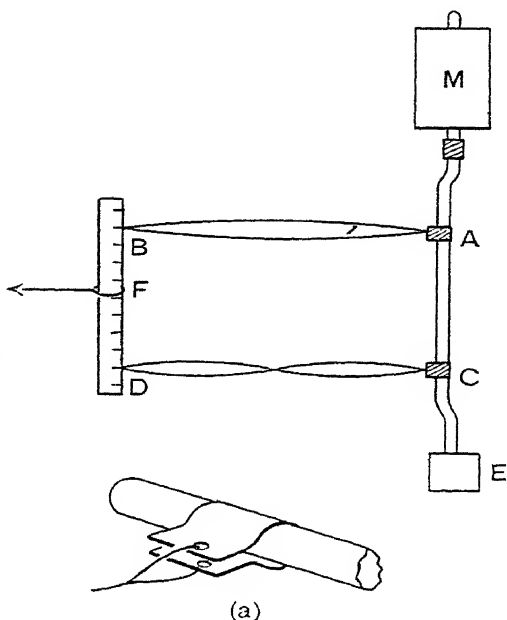
the single string CD is retained but AB is replaced by a string made by plaiting two single strings together. If the plaiting is quite loose the mass per unit length of the compound string is approximately twice that of the single one A position for the ring F is then found so that the strings AB and CD both vibrate with the same number of loops. It will be found that FD = 2BF. Using 3, 4 or 5 plaited strings for AB, F divides BD in the ratio 1 . 3, 1   4 or 1 : 5 respectively. Thus, if the tensions and mass per unit length are increased proportionately no change of wavelength occurs

Again, using a four-stranded string, F is placed at the mid-point so that the tensions are equal   When CD vibrates in one loop, AB vibrates in two or the wavelength is halved if the mass of unit length is increased four times

A Source of Radiation (E. Denne)

The ideal source of thermal radiation would be small in size, constant in output, easily varied in temperature and should reach a steady state in a reasonably short time

The apparatus to be described represents an attempt to achieve these properties   It has a base consisting of a piece of asbestos sheeting, through which are mounted a pair of $\frac{1}{4}$-inch brass rods, screwed 4 B A at each end. Two nuts on each fix them to the base, so that a couple of inches protrude on one side.   A terminal nut is used to make connection on the shorter side, while on the long side a resistance element is clamped between two nuts on each rod, at the far end   The resistance element consists of 15 cm. of nickel chrome wire (taken from an old electric fire), 26 gauge, coiled into a small spiral, looking rather like a magnified car headlamp filament.   This is used on a 6-volt battery, and takes about 5 amperes.   The full radiating power is obtained very quickly because the element is sufficiently far from the base. The ordinary commercial radiator is in thermal contact with a fireclay mounting, which interferes considerably with the output.   The current may equally well be taken from A.C. mains using a 6-volt transformer, and a second spiral may be paralleled if required.

The apparatus is particularly suitable for showing the selective absorption by glass, etc   The radiator is placed at a fixed distance from the thermopile, and the fractional change in reading is noted when a sheet of glass is interposed. The temperature of the radiator is then reduced by means of a series rheostat, and the fraction determined again.

The following results are typical (obtained by a member of the sixth form) :

Current		Galvo reading	Galvo reading (through glass)	Fraction of radiation transmitted
2 0 amp.	.	1·9	0·2	0 1(1)
3·0 ,,	.	8·2	2 4	0 29
4·0 ,,	.	18 0	6 9	0 38
4 8 ,,	.	28·2	13·9	0 49

The specimen of glass was an ordinary microscope slide

Simple Apparatus for Demonstrating the Condensation of Water Vapour on Small Nuclei (J. Kewley)

The apparatus required is a pint clear-glass bottle and a motor-tyre hand-pump.

The piston washer of the pump is reversed so that the pump functions as a suction pump.   The small valve at the foot of the pump is removed and a piece of thick-walled rubber tubing fitted.   This leads to a glass tube through a rubber bung in the bottle   The air in the bottle is kept moist by a damp sponge in the bottom.

The expansion produced by a sudden sharp pull on the pump is sufficient to cause the necessary reduction of temperature to produce a heavy cloud after a slight whiff of cigarette smoke has been introduced. Without the smoke no cloud is obtained.

If one half of the bottle is covered by black velvet and the bottle is stood in the light of an electric torch the cloud formation can be strikingly demonstrated to a large class.

Cooling Produced by Evaporation (W. J. Sparrow)

An effective demonstration of this is obtained by using a simple junction of copper and Eureka wire with a sensitive galvanometer. The junction is dipped in ether and then removed. Water will show the effect.

Experimental Determination of Hysteresis Curves (D. Owen Jones)

Many text-books include a description of the magnetometer method for obtaining the hysteresis curve for a specimen of magnetic material, but it is very seldom that sufficient details concerning the dimensions of the magnetizing coil, the compensating coil, and the specimen are given in order that a satisfactory curve may be obtained.

It has been found that satisfactory results may be realized and that good curves may be obtained by using the apparatus described below.
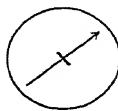
The Magnetizing Coil A

This consists of two layers each of 440 turns of 18 S.W.G. copper wire, wound on a brass or copper tube 70 cm. long and 1 cm. in diameter. (A brass curtain rod serves the purpose admirably.) The excess length of coil necessary to allow for the " end effect " is always a subtle point, but consideration of the results of preliminary experiments seem to indicate that this length of coil is necessary in order to ensure that the whole of the specimen should be subjected to a uniform field.

The Compensating Coil B

The length of the compensating coil need only be fairly short as its position may be adjusted close up to the magnetometer scale in order to produce the necessary field for compensation. For this purpose the coil used was 14 cm. long and consisted of 8 layers each of 80 turns, the wire used being similar to that used in the magnetizing coil.

The Specimen S

A suitable length for the specimen is about 30 cm., and the diameter should be about 0·3 or 0·4 cm., and it may be fixed co-axially with the coil by means of a cork fitted near each end. To obtain a curve which represents the hysteresis of a magnetic material, e.g., of a steel, good results may be obtained by using a rod of silver steel (obtainable at most tool shops at a few pence per foot). A current of 5 amperes is sufficient to produce saturation in a specimen of silver steel 30 cm. long and 0 32 cm. in diameter, and as the total resistance of both coils is less than 2 ohms, a small battery of accumulators is sufficient to supply the desired voltage.

15

A Simple Form of Shadow Photometer with Certain Photographic Applications (G. C. Curtis)

The exposure required in photographic enlargement, always a matter of some uncertainty, is usually determined by exposing strips of a test piece of bromide paper for successively increasing times. This can, however, be avoided if means are available to ascertain

(*a*) the intensities of illumination of the lightest and darkest parts of the projected image, and

(*b*) the " speed " of the bromide paper used.

Scale ⅕ size

FIG. I.
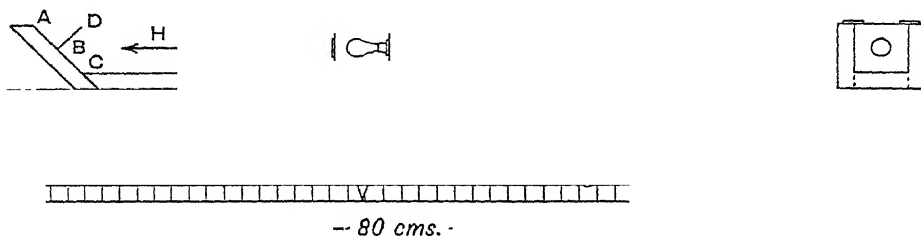
If the latter is determined once and for all, a suitable exposure may be made at once by a simple photometric measurement of the image. A modified shadow photometer designed for this purpose has been found to be adaptable also as a " reflection densitometer " and although it is not an instrument of high precision it affords an instructive introduction to the " characteristic curves " of silver emulsions which can usually be plotted only by the use of expensive apparatus.

Principle

A small white screen AC, shown in Fig. 1 and set at 45° to the horizontal, is divided into two equal parts by a thin blackened vane BD set at right-angles to it. If the screen be placed upon the base of a vertical photographic enlarger, the image-forming beam V will illuminate the upper portion AB but be screened by the vane from the lower portion BC. If a horizontal beam of light, H, be provided at right-angles to V, it will similarly illuminate the lower portion BC but be screened by the vane from the portion AB. Thus the eye placed in the plane of BD, where BD will appear as a fine line, can compare accurately the intensities of illumination of AB and BC. If H be derived from a constant source movable horizontally, the position of the source at which AB and BC appear identical will be a measure of the intensity of illumination of AB.

Construction

The instrument consists of a shallow plywood trough, 80 cm. long, and 3 cm. square in cross-section, blackened internally except at one end, which is inclined at 45° to the horizontal and lined with white card. This card is the screen AC (Fig. 1); and the vane BD, of thin blackened metal, is slotted into the sides of the trough, at right-angles to it. The adjustable source of light is the ground-glass front of a small metal lamp-house which is free to slide from end to end of the trough and contains a 4·5 volt pea-lamp under-run from a 2-volt accumulator. (The redness of the light so produced causes no diffi-

culty in matching the brightnesses of AB and BC.) Even so, the illumination may be too great unless a neutral-tinted filter be placed between the lamp and the ground-glass. The lamp-house carries indicators which move over scales on both top edges of the trough, the one being a scale of foot-candles and the other a scale of densities.

Calibration and Use as a Photometer

A very approximate scale for the instrument may be calculated directly, but it is preferable to derive the scale experimentally. For this purpose the intensity of illumination upon the easel of a " vertical " photographic enlarger is varied over a wide range and at each variation it is measured first by means of a photronic cell and galvanometer,[1] which may be assumed to have a linear response to light, and then by matching it upon the screen of the photometer. A few points determined in this way give the data for constructing a complete inverse-square law scale, the range of which may be still further extended by the use of neutral-tinted filters fitted in a slot at the front of the lamp-house. The arbitrary scale thus prepared is adequate for most purposes, but if access is possible to a Weston illumination meter or similar instrument, then it may be renumbered in terms of foot-candles.

Calibration and Use as a " Reflection Densitometer."

It is now required to measure the reflection density D of a surface (e.g., a uniform portion of a print upon bromide paper), which is defined as

$$\log_{10} \frac{\text{light falling on surface}}{\text{light reflected diffusely}}$$

For this purpose the instrument is slightly modified so that the upper portion AB of the inclined screen can be replaced by the surface, the reflection density of which is to be determined. If with a white surface upon both AB and BC and with the lamp at some short distance s_1 from the screen, a vertical source of light is adjusted to give equality of illumination of both portions of the screen, then on replacing the upper portion AB by a surface of density D, a movement of the lamp to some greater distance s_2 will be required to make both portions of the screen again appear equally bright. Now it can be shown that $D = 2 \log s_2 - 2 \log s_1$.

For : let I_1 = illumination of upper screen throughout
= illumination of lower screen at first
I_2 = illumination of lower screen finally.

Then $D = \log \dfrac{I_1}{I_2}$ by definition (assuming lower screen has zero density).

But $I_1 = \dfrac{L}{s_1{}^2}$ and $I_2 = \dfrac{L}{s_2{}^2}$ where L = illuminating power of lamp-house.

$\therefore D = \log \dfrac{I_1}{I_2} = 2 \log s_2 - 2 \log s_1$ as above.

It is convenient to fix on the unoccupied side of the wooden trough a scale divided according to the law : Reading = twice log of distance from origin. This reads densities directly. Moreover, the intensity of illumination is immaterial, provided that it does not vary during the experiment, since the

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[1] If a photronic cell is not available a standard candle and optical bench can, of course, be used instead. This method, while less accurate than the one described, renders the subsequent use of an illumination meter unnecessary.

density of any surface may be determined merely by subtracting the initial reading with both portions of the screen white from that observed when the given surface covers the upper portion of the screen.

A *Photostat*
B *Photomechanical*
C *Tonelle Vigorous*
D *Tonelle Normal*
E *Tonelle Medium*
F *Tonelle Hard*
G *Plastika Vigorous*
H *Plastika Ordinary*

2·0

DENS.

1 0

A   B   C D   H   G   F   E

·025   ·1   ·4   1·6   6·4   25 6

EXPOSURE IN FOOT-CANDLE SECONDS
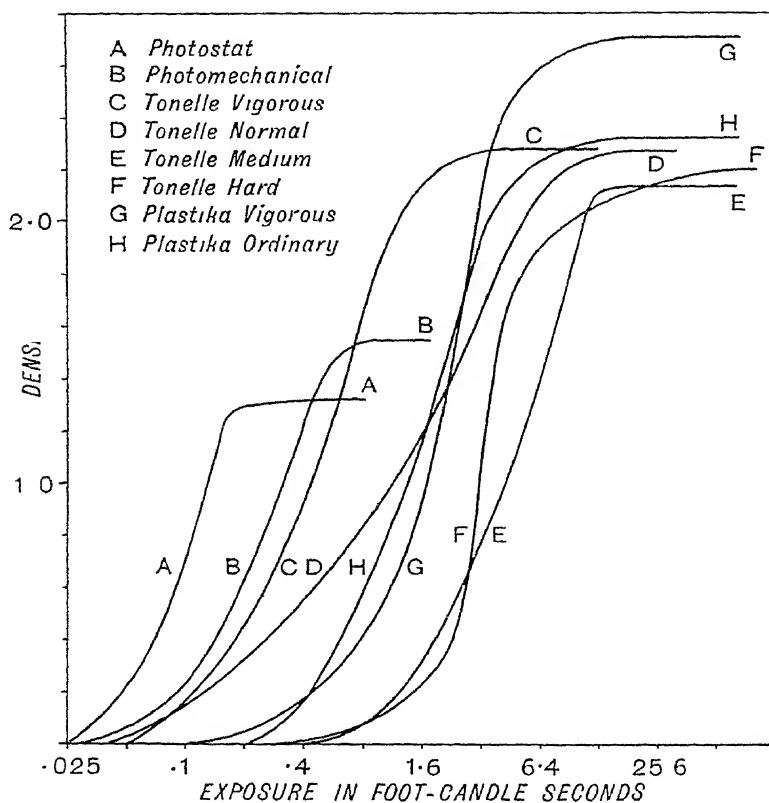
FIG. 2.

Fig. 2 shows a family of characteristic curves obtained in this way.   It will be noticed that no account is taken of any failure in the " reciprocity law."

I wish to express my thanks to Dr. L. A. Sayce of King's College, New-castle-upon-Tyne, for supervising this work.

BIOLOGY AND CHEMISTRY NOTES

Meiosis in Pollen Mother Cells (VIth Form Boys, Westminster School, sent by L. H. Burd)

The examination of reduction divisions, and chromosome counting in pollen mother cells, is generally considered to be much too advanced for
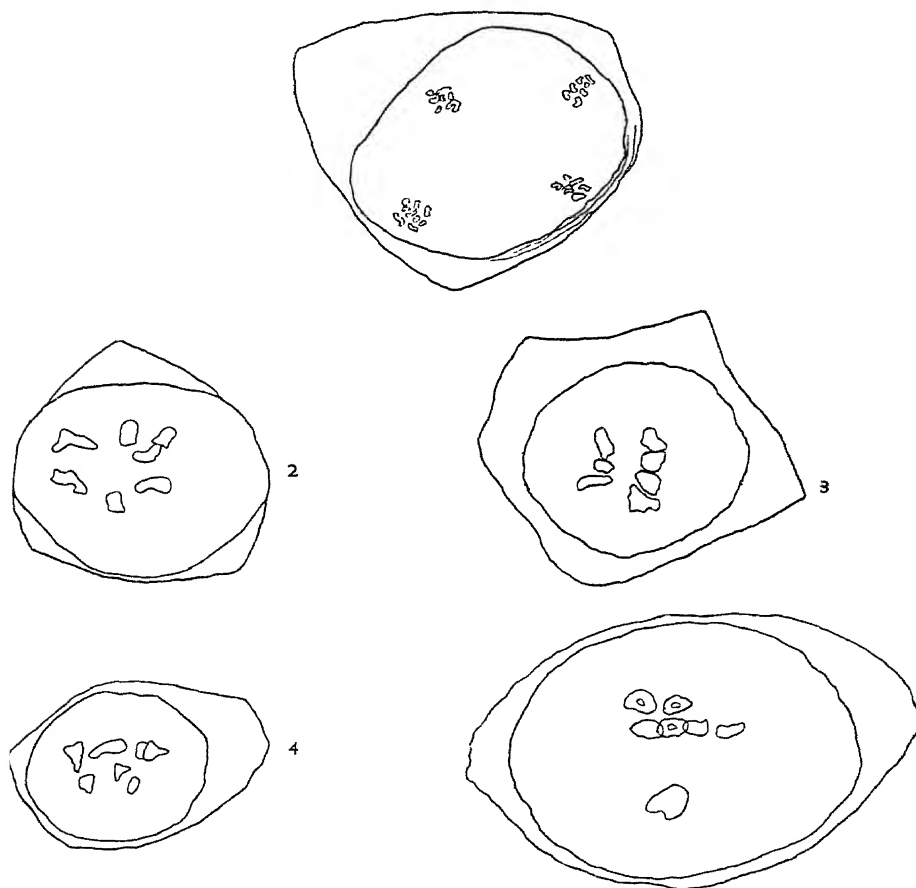
FIG. I.—Late anaphase of 2nd division
FIGS. 2–5 —Metaphase of 1st division

school pupils, but if suitable methods and material are chosen it has been found to be well within the capacity of VIth form boys and to need very little time. Excellent results have been obtained as follows : Flower-buds of *Lathyrus latifolius*, the everlasting pea, are taken, and their anthers treated by

Belling's aceto-carmine method. This plant offers several advantages. It produces a succession of flower buds throughout a considerable period of the summer. The buds and anthers at the reduction stage are large enough to be handled quite easily. The small number and large size of the chromosomes makes counting quite easy with a $\frac{1}{6}$-inch objective, and an oil immersion is quite unnecessary. Buds 6 0 to 7·0 mm. long show chromosomes at metaphase in about 50 per cent. of the trials. The buds are opened and the anthers extracted and teased on a slide with steel needles, for about 15 seconds, in a drop of a saturated solution of carmine in 45 per cent. acetic acid. This dislodges the pollen mother cells and introduces enough iron into the carmine for satisfactory staining. A cover-slip is added and the preparations are ready for use They are not permanent, but can be kept in reasonable condition for a day or two if the cover-slips are sealed with vaseline.

The accompanying drawings, and the preparations from which they were made, were completed unaided in one period of $1\frac{1}{2}$ hours by a form of six boys, five of whom were successful in making preparations in which the seven bivalent chromosomes could be counted with ease and certainty. The majority of the preparations showed all stages from early prophase to the completion of meiosis.

Standardization of Volumetric Solutions of Acid and Alkali (E. H. Coulson and L F Ennever)

The method of standardizing acid and alkali solutions used by Koszegi (*Z. anal. Chem*, 1938, **111**, 343–8) provides a useful alternative procedure for sixth-form work, since it involves no primary standard reagent.

The alkali solution is titrated with acid, a suitable indicator being used. Equivalent volumes of the two solutions are mixed, the salt solution evaporated to dryness in a weighed porcelain, silica or platinum dish and the dry salt weighed. From the results obtained the strength of both solutions can be calculated.

Results obtained with this method, for sodium hydroxide and hydrochloric acid solutions of approximately normal strength, are compared below with those of two common methods of standardization.

Method I. Köszegi's Method. 25 c.c. NaOH solution titrated with HCl solution, using screened methyl orange as indicator. Neutral solution made in proportions found by titration, evaporated to dryness in weighed porcelain dish (water-bath + air oven) to constant weight. Weights of NaCl obtained in duplicate experiments—1·4499 gm. and 1 4513 gm.

Method II. Titration of weighed quantities of pure Na_2CO_3 with HCl solution, using screened methyl orange as indicator.

Method III. Titration of weighed quantities of pure oxalic acid with NaOH solution, using phenolphthalein as indicator.

Method.	Normality of HCl Solution.	Normality of NaOH Solution
I	1·154	0 993
	1·155	0 994
II	1 152	—
	1·152	—
	1·158	—
III	—	0 988
	—	0 988
	—	0·987

By weighing to 0·1 milligram the method should be quite accurate for N/10 solutions.

It is worth noting that the residue of NaCl obtained, dissolved in water and diluted to 250 c c., provides sodium chloride solution of convenient strength for the standardization of N/10 silver nitrate solution.
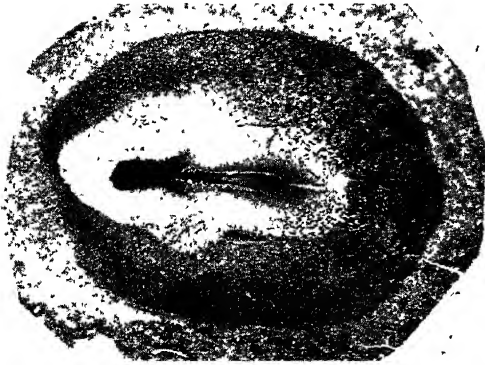
Chick Embryo. 24 hrs × 4.
$\frac{1}{10}$ sec at f 12.
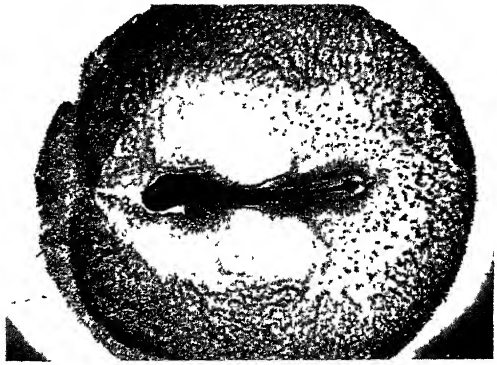
Chick Embryo. 48 hrs. × 4.
$\frac{1}{10}$ sec at f. 12.
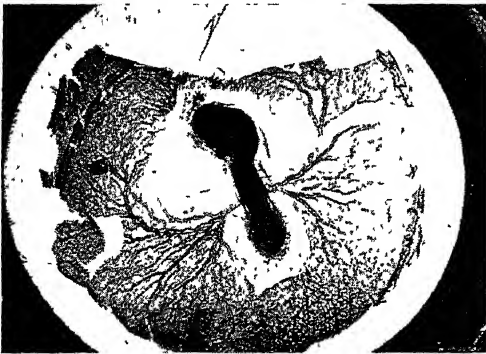
Chick Embryo. 60 hrs × 2½.
$\frac{1}{25}$ sec. at f. 7.
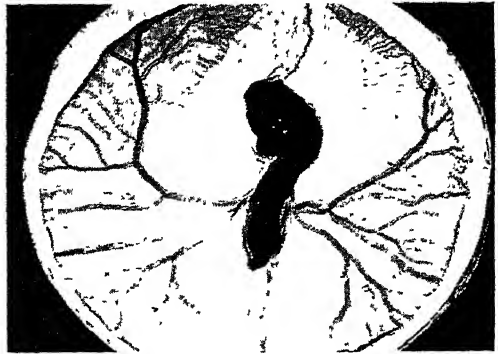
Chick Embryo. 72 hrs × 2½
$\frac{1}{25}$ sec. at f. 7.
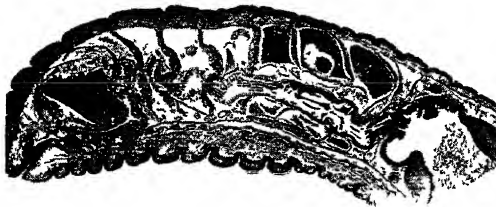
Lumbricus L S. Body. × 4
Reproductive Region $\frac{1}{10}$ sec. at f. 12.

Photomicrographs intended to be of general biological interest. Taken with a Leica Panphot on Ilford Process Panchromatic Plates, using a green filter.
L. F. and M. G. Ennever.

The Percentage of Oxygen in the Air (E. H. Coulson and L. F. Ennever)

This apparatus was devised to demonstrate to junior forms that the air contains approximately one-fifth of oxygen by volume, the usual bell-jar method having been found to give low results. In the method described, air is passed over burning phosphorus.

The bottles A and B are Corbyn Quarts (about $1\frac{1}{2}$ litres capacity), A being divided into 5 equal parts by measurement of the volume of water required to fill it to the bottom of the rubber stopper ; the graduation marks are painted on the outside of the bottle. The phosphorus is contained in a straight form calcium chloride tube, the bulb of the tube being loosely packed with asbestos-wool to prevent distillation of phosphorus into bottle B.
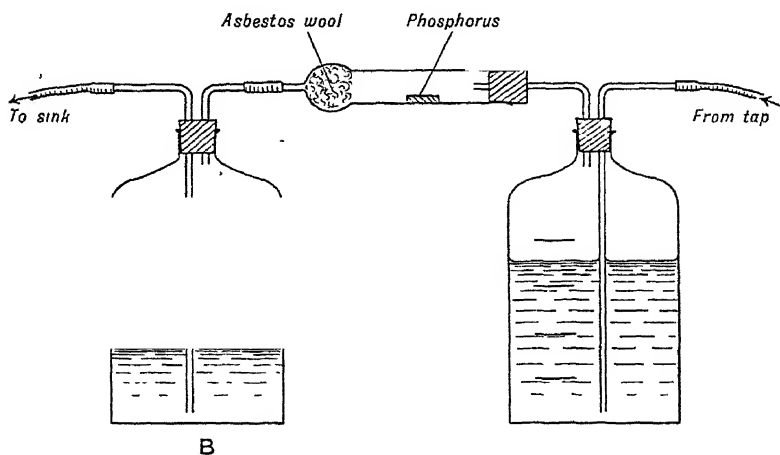
When the experiment begins, A contains air and B is filled with water. A is connected to the tap with rubber tubing and the outlet from B to the sink. It is convenient to use red rubber tubing for one of these connections and black rubber tubing for the other. A small stick of yellow phosphorus (about $\frac{1}{4}$-inch long) is placed in the calcium chloride tube and ignited by gently warming the outside of the tube with a small flame. Air from bottle A is then passed over the burning phosphorus by running in a slow stream of water from the tap.

The rate of flow of air is adjusted so that the phosphorus flame is just visible ; about 15–20 minutes should be taken to fill A with water. The slow passage of air is very important since, if the phosphorus burns too fiercely, the calcium chloride tube will crack and burning phosphorus scatter on the bench. When A is just filled with water, the tap is turned off, the rubber tubing leading to it closed with a screw clip and removed from the tap. The rubber tubing from B is now connected to the tap, the clip opened and the air in B sent back into A until B is filled with water. This operation can be carried out quickly, since most or all of the oxygen has been removed from the air. It is now found that water remains in A to the first graduation mark, hence one-fifth of the original volume of air has been removed by passage over burning phosphorus.

Experiments to Illustrate the Effect of Varying Conditions on the Velocity of a Chemical Reaction (E. H. Coulson and L. F. Ennever)

Few textbooks seem to indicate the general usefulness of the reaction between potassium iodate and sulphurous acid in introducing the factors which

affect the velocity of a chemical reaction. The following experiments are based on those described in Bjerrum's *Inorganic Chemistry* (Heinemann, 1936, pp. 66–7), with certain modifications as to quantities of reagents and some additions.

The reaction studied is the oxidation of sulphurous acid by means of potassium iodate,

$$KIO_3 + 3H_2SO_3 = KI + 3H_2SO_4 \qquad . \qquad . \qquad . \quad (i)$$
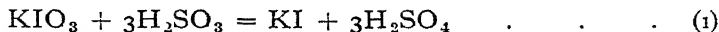
the time taken for the reaction to go to completion being used as a measure of the velocity with which the change proceeds. The completion of the reaction is easily observed since the subsequent reaction is

$$KIO_3 + 5KI + 3H_2SO_4 = 3K_2SO_4 + 3H_2O + 3I_2 \qquad . \quad (ii)$$
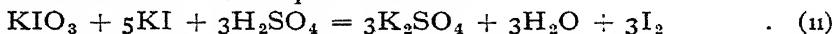
Reaction (ii) cannot proceed until reaction (i) is complete owing to the rapid reduction of iodine by sulphurous acid. In the presence of starch a blue flash spreads over the whole mixture as soon as reaction (i) is complete. It is obvious that potassium iodate must be present in excess.

Reaction (i) is catalysed by hydrogen ions and hence the effects of concentration, temperature and presence of a catalyst on the velocity of the reaction may be studied.

The solutions needed are :

A. Potassium iodate 20 gm./litre.

B. Sulphurous acid 20 gm. SO_2/litre. This is best prepared by passing the gas into a known volume of water until the required gain in weight has been obtained. No special accuracy is needed.

C. A dilute starch emulsion.

Various solutions of acids of known strength are necessary for showing the catalytic effect.

The following method of procedure has been found convenient.

Measure the required volumes of solutions A and B, from burettes, into separate measuring cylinders (100 c.c.) each containing 40–50 c.c. distilled water. Add a few drops of C to the cylinder containing B and make up the contents of each cylinder to 100 c.c. with distilled water, stirring each with a long glass rod. Pour diluted B + C into a 250-c.c beaker, add diluted A and note the time of addition, stir for 2–3 seconds and time the appearance of the blue flash. When other solutions have to be added this is done to B + C before the final dilution. To show the effect of temperature, warm water is used. Using this method, the total volume is always about 200 c.c.

Some results obtained are shown in the tables ; duplicated results are to give some idea of the reproducibility possible under the conditions employed.

TABLE I

EFFECT OF CONCENTRATION

Temperature 9° C.

Volume of KIO_3 Solution (A). (c.c.)	Volume of SO_2 Solution (B). (c.c.)	Time for Completion of Reaction (i). (secs.).
5	2	193
5	3	103
5	4	70
5	5	53, 55, 53
5	6	47
5	7	>900 (SO_2 now in excess)
6	5	41
8	5	29
10	5	22, 23
10	10	8

Note.—The reaction is more complicated than is indicated by equation (i), hence the effect of concentration can only be shown qualitatively.

TABLE II

EFFECT OF TEMPERATURE

5 c c Solution A + 5 c.c. Solution B used for each Experiment

Temperature (°C.).	Time for completion of Reaction (1). (secs.).
9	53
24	42
46	17

TABLE III

EFFECT OF ADDITION OF ACIDS

5 c c. Solution A + 5 c.c. Solution B used for each Experiment
Temperature 9° C.

Acid added.	Time for completion of Reaction (1) (secs)
None	53
1 c c N. HCl	27
2 c c N. HCl	16, 16
4 c c N HCl	8·5, 8 5
2 c.c. N H_2SO_4	21
4 c.c. N. H_2SO_4	12
8 c c N H_2SO_4	7 5, 8
2 c c N CH_3COOH	53
10 c c. N. CH_3COOH	51

Table III shows that the reaction can be used to show the relative strengths of acids. This should be capable of much expansion.

Willard's Preparation of Perchloric Acid (G. Fowles)

The digestion of ammonium perchlorate in aqua regia affords a concentrated solution of perchloric acid. The reaction was discovered by H. H. Willard in 1912.

Place 25 gm. of crushed ammonium perchlorate in a flask (150–300 c.c.), add 30 c.c. of water and dissolve the salt (or most of it) by bringing the water to the boil. Remove the flame, add 11 c.c. of ordinary concentrated nitric acid ($d = 1·42$) and again bring to the boil. At intervals, run in from a burette a solution of 4·5 c.c. of concentrated hydrochloric acid in 30 c.c. of water, keeping the preparation liquid vigorously boiling all the time. The addition of the hydrochloric acid takes about 5 minutes   During this addition the volume of the boiling solution should be kept approximately constant in order to have the ammonium perchlorate at its maximum concentration. Continue the vigorous boiling for an hour, adding water from a burette to keep the volume constant. At the end of this time cease the addition of water and evaporate until dense white fumes (of $HClO_4.2H_2O$) appear. These fumes are easily distinguished from the steam. Allow the liquid to cool. The liquid should be now free from ammonium perchlorate. To make quite sure, test a small portion with caustic soda. Should ammonia be detected, dilute the preparation liquor to its original volume, add 6 c.c. of concentrated nitric acid and repeat the first process, running in a corresponding quantity of the dilute hydrochloric acid. Boil for another ½ an hour, then evaporate as before. Stand for 24 hours, then pour off the perchloric acid from any solid deposit, for when all the ammonia has been removed a turbidity or even a solid deposit sometimes appears, probably due to impurities in the ammonium perchlorate.

The stable solution thus obtained consists of 72 per cent. $HClO_4$ and 28 per cent. H_2O ; it therefore corresponds to $HClO_4.2H_2O$. But it is a constant boiling-point mixture (b p. 203° C). The yield is quantitative.

Comment

The above procedure is slightly modified from that in Willard's paper (*Jour. Amer. Chem. Soc*, 1912, **34**, 1480). Willard states that one digestion with nitric acid usually suffices to remove the ammonia completely and to leave a solution of pure perchloric acid. We, at Latymer, have always found it necessary to repeat the digestion at least once more, with a second portion of nitric acid. From his investigations Willard concluded that the preparation reaction was exceedingly complex. He believed that the ammonia was oxidized away, and that the oxidizing agent was not nitrosyl chloride or chlorine, but nascent nitrous acid. He found that 90 per cent. of the gas evolved was nitrous oxide ; the rest chiefly chlorine. These results forced him to suggest the following complicated equation

$$34NH_4.ClO_4 + 36HNO_3 + 8HCl = 34HClO_4 + 4Cl_2 + 35N_2O + 72H_2O.$$
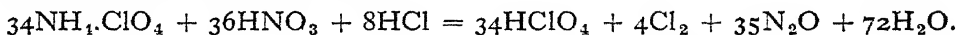
It has often seemed to me desirable to seek a simpler explanation of the reaction. Thus, consider the evolved chlorine. It has obviously taken no part in the reputed oxidation process, but is due to a concurrent reaction—the decomposition of some of the aqua regia. In other words, the only gaseous product of the main reaction is nitrous oxide. It is therefore possible that the production of perchloric acid is not due to oxidation at all, but to the formation of ammonium nitrate by metathesis, followed by its decomposition by heat. I therefore venture to suggest replacing the cumbersome equation of Willard by the simple one

$$NH_4 ClO_4 + HNO_3 = HClO_4 + N_2O + 2H_2O.$$
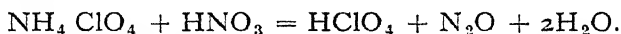
R. E. Goddard, scholar of the Imperial College, when in sixth form at school began a study of the reaction He found that with nitric acid alone no perchloric acid was produced Hydrochloric acid must be present, yet the quantity added had no apparent effect either on the speed of the action or the yield obtained. We therefore tentatively concluded that the function of the hydrochloric acid was that of a catalyst.

The Burning of a Candle (H. G. Andrew)

The burning of a candle in a jar over water still appears in some textbooks, even recent ones, as an experiment to find the fraction of the air used in burning. It so happens, that if an inverted gas-jar is quickly lowered over a burning candle in a trough of water, the water rises something like a fifth of the way up the jar. This is chiefly a result of the expansion of the air in the jar as the jar is lowered over the flame. Any result between about a tenth and a half can be obtained by varying the size of the flame and the rapidity with which the jar is put over the flame.

A candle flame burning in a closed space goes out when the percentage of oxygen in the air falls to about 16 per cent. ; and the air then contains about 3 per cent. of carbon dioxide The real reduction in total volume is only about a fiftieth.

The investigation of this experiment was suggested by the fact that the cabins of fishing trawlers are often so securely sealed during winter nights that the oil lamps go out, but the occupants appear to come to no harm.

SCIENCE TEACHING FILMS

Abstracts of reviews taken, by kind permission, from the Monthly Film
Bulletins of the British Film Institute.

APPLIED SCIENCE

Steam Power (U.S.A.), 1935

16-mm. silent, 400 feet, 8-mm. silent, 16 minutes, 1 reel. Teaching
notes available.

Distributors : Kodak, Ltd., Wealdstone, Harrow, Middlesex.

Contents : The opening scenes of the film show two of the more spectacu-
lar adaptations of steam power, the steamship and the locomotive, typifying
transportation, after which Watt's early steam engine appears diagrammatically
with labels showing the action of the various parts. The application of
Watt's engine follows in a replica of the first steamboat *Clermont*, on the
Hudson River. The second part of the film deals with simple (one-cylinder)
steam engines, as distinct from compound or multiple expansion engines,
with close-up views of the mechanism, and labelled moving diagrams. The
next section deals with steam boilers, and the film closes with shots of early
locomotives, followed by more modern types, with a description of the way
in which they work.

Appraisal : This film contains a great deal of good material, but attempts
to cover too great a field to be satisfactory. It could with advantage be divided
into at least three films, on boilers, steam engines and locomotives, and pos-
sibly also an historical film. Because of its wide scope it is lacking in con-
tinuity. The teaching notes, however, are good, and contain sufficient material
for the teacher to give a preliminary lesson on the subjects demonstrated,
and an adequate running commentary while the film is being shown. The
film would only be of use to people already possessing a certain amount of
knowledge of the subject

Suitability : For classes 14–19, and as a background film, for students
already having some knowledge of the subject.

BOTANY

Fit to Boil (Great Britain), 1932

35-mm. S.-on-F , 16-mm. S.-on-F., 819 feet, 10 minutes, 1 reel. Com-
mentary supplied if required.

Distributors : British Instructional Films, 111 Wardour Street, London,
W.1.

Contents : A present-day potato tuber and the uneven ancestral type
are shown, and the process which has led to the production of the modern
type is made clear by a close view of an operator carrying on cross-pollination
between two potato plants, followed by a diagram of the growth of the pollen
tube down the style and the fertilization of the ovules. The berry [*sic*] is
planted, the root and shoot develop and a small tuber is produced by an under-
ground shoot ; this development takes six weeks. A close view of a sprouting
tuber shows the need for the removal of some of the " eyes," after which the

tuber is planted in a shallow trench and covered with soil. The " eyes " which remain grow into aerial shoots, from the base of which roots grow downwards. A magnified view of one of the stem hairs shows circulating protoplasm. Finally, the serial shoots die and the plant with its new tubers is lifted ; this is done by means of a plough which breaks up the soil and a fork which separates the tubers.

Appraisal : A clear and interesting film giving an accurate account of the life-history of the potato plant and of the practical processes which accompany its cultivation.

Suitability : For use in the teaching of gardening, botany and biology. As a classroom instruction film for pupils of 12 +. As a general interest film for any age, and useful for showing to gardening clubs and natural history societies.

Grade : I.

From Flower to Fruit (U.S.A.), 1929–30

16-mm. silent, 400 feet, 15 minutes, 1 reel.

Distributors : Kodak, Ltd , Wealdstone, Harrow, Middlesex.

Contents : The floral parts of the rose are shown in photographs of the flower at different stages and in a diagram of the essential organs ; the process of pollination is made clear by photographs of a lily flower and microphotographs of pollen grains ; different insects are then seen visiting the lily flower and a bee covered with pollen is shown on the capitulum of a composite. The lily flower is used to show cross-pollination by a human operator. By means of microphotographs and diagrams we see how fertilization takes place, pollen grains germinate on the stigma, the male nucleus passes down the tube and fuses with the egg nucleus in the embryo sac of the ovule. The development of fruits of the rose and the lily follows ; and in more detail, by means of photographs and diagrams, the relation is shown between apple flowers and the apples that are produced.

Appraisal : A good film with some attractive close-up views of opening flowers : the parts of the flower and the structure of the fruits are clearly shown, but intermediate stages of fruit development are omitted. An unusual feature is the clear microphotography of the developing pollen grain in the tube of which the male nuclei are seen quite distinctly. The film shows well the part played by pollination and fertilization in fruit formation

Suitability : For use in the teaching of botany and biology. As a classroom instruction film for pupils of 12 + if details of embryo sac are omitted, and for pupils aged 15 if this is retained As a general interest film for natural history societies.

Grade : II.

Leaves and the Sensitive Plant (France).

16-mm. silent, 9 minutes, 1 reel. Teaching notes not available.

Distributors : Ensign, 88/9 High Holborn, London, W.C.1.

Contents : (1) *Leaves.* After an introductory woodland scene, photographs of leaves are shown in illustration of various features ; we see the vetch leaf with stipules, the rhubarb leaf with a sheathing base, different kinds of venation in lime, Ginkgo and iris, compound leaves, variation in leaf shape in grape vine, virginian creeper, oak, eucalyptus, violet, basifugal development in acacia and basipetal development in the rose. Sleep movements are seen in mimosa. Modified leaves are then shown ; protective scales in winter bud of lilac, swollen bulb of lily, tendrils in grape vine, and colocinth, and spines of holly. The film ends by showing polymorphism in the leaves of the water buttercup.

(ii) *The Sensitive Plant.* Leaf movements are shown in response to the stimulus of contact in the sensitive plant, *Mimosa pudica.* The plant is first seen from all sides in a revolving pot ; the collapse of the petioles and leaflets is then shown after light touches on various parts of the leaf, and the direction of propagation of the stimulus is shown.

Appraisal : Good photographs of the variety of form in leaves and leaf movements, but the rate is too fast and much more explanation is needed.

Suitability : For use in the teaching of botany. As a revision film for pupils of 14+. It is too morphological to be of general interest.

Grade : II.

Magic Myxies (Great Britain), 1931

35-mm. S.-on-F., 16-mm. S.-on-F., 956 feet, 11 minutes, 1 reel. Commentary supplied if required.

Distributors : British Instructional Films, 111 Wardour Street, London, W.1.

Contents : Introductory shots are seen of *Myxomycete sporangia.* They dehisce, and the germination is seen of the spores to swarm cells, each with a flagellum. Fission and the retraction of the flagellum to the myxamœba state is shown by diagrams. Ingestion of bacteria by the myxamœba is indicated, and plasmodium formation by the fusion of myxamœba follows. Those which fail to fuse are devoured. The flowing and rhythmic circulation of the reticulated plasmodium is clearly shown under high pressure. Plasmodia are seen to enlarge and to fuse amongst themselves. A " myxie " is seen feeding on a leaf, on a toadstool, and then the response to poisons, arsenic and Epsom salts, is seen. Shots follow of the formation of a sclerotium with the advent of cold or drought. A very beautiful sequence is shown of a myxomycete crossing a gossamer thread to reach a mushroom. Fruit formation and a shot of dehiscing sporangia completes the film.

Appraisal : This film left us in a very unsettled frame of mind. Photographically, it is an excellent portrayal of a rather difficult subject of limited appeal. The camera work of this series of films is always worth watching for itself. But we are bound to ask if it is necessary to provide a film of this type with such an unsuitable commentary.

Suitability : For use in the teaching of botany. It would be probably best suited to advanced university students, as a silent film and not a talkie, and also for showing to natural history societies.

Grade : II.

Peas and Cues.

35-mm. S.-on-F , 16-mm. S.-on-F., 833 feet, 10 minutes, 1 reel. Commentary supplied if required.

Distributors : British Instructional Films, 111 Wardour Street, London, W.1.

Contents : The film begins with a close view of a pea seed in the soil, following by stages of germination which extend over five days. A realistic group of young seedlings is shown with circumnutating tendrils, followed by a close view of the tendril and its movements. Flower structure and method of germination are then shown ; we see the opening and shutting of the flowers according to the stage of development and the time of day, the position of the stamens and gynœcium in the keel by means of a model, and the working of the pollination mechanism with the help of living insects and a model bee. The pollen grains (× 2000) germinate in the stigma and a pollen tube (× 30,000) grows down the style. A diagram shows the passage of the tubes in the ovules, and the ripe pod is seen dehiscing and shooting out the seeds.

The importance of suitable soil for germination is shown by the appearance of seedlings which develop on hard and soft ground respectively.

Appraisal : An accurate and interesting film which is accompanied by a good and suitable commentary.

Suitability : For use in the teaching of botany and biology. As a class-room instruction film for pupils of 13+. As a general interest film for any age from 13 onwards.

Grade : I.

CHEMISTRY

Development of the Photographic Image (Great Britain), 1931

16-mm. silent, 800 feet, 32 minutes, 2 reels. Teaching notes not available.

Distributors : Kodak, Ltd., Wealdstone, Harrow, Middlesex.

Contents : The film demonstrates the making of the emulsion and the development of the exposed film, with animations showing the chemical reactions, together with an exposition of the Trevelli theory of photo-sensitivity.

Appraisal : This is a very highly specialized film, containing a certain amount of valuable material. It is felt, however, that the arrangement of the material is unsatisfactory, owing to an attempt to combine elementary and advanced treatment of the subject in one and the same film : in fact, one gets the impression that at least two shorter films have been put together with no very clear objective in view. The two-reel film could have been satisfactorily divided into two, showing (1) the making of the emulsion on a small scale, the large-scale equivalent and the coating of the film, development and fixing processes, all treated in a simple manner and suitable for school use as a chemistry or general scientific interest film, and (2) the detailed consideration of the chemistry and microscopy of the development of the latent image, with present-day theories, suitable for photographic societies, technical institutions, etc. As it stands, only a small section of the film has any value as an adjunct to the usual school work, and it would need a great deal of explanation from the teacher to make it intelligible. The photography is uneven, the microphotography being poor. The film is disappointing in view of the great resources which lie at Kodak's disposal.

Suitability : Not suitable for schools, but might be of interest to a school science society interested in photography, or a technical institute.

GEOLOGY

Limestone and Marble (U S A.), 1934

16-mm. silent, 8-mm. silent, 400 feet, 16 minutes, 1 reel. Teaching notes available.

Distributors : Kodak, Ltd., Wealdstone, Harrow, Middlesex.

Contents : A party of boys is seen being conducted through a gorge near Rochester, New York, and their attention is directed to the limestone and its fossils, after which the use to which limestone is put in road building is shown. After a classroom interlude on chalk, the quarrying of limestone and its working up for building purposes is shown, followed by the preparation of lime and cement from limestone. The last part of the film deals with marble, which is seen being quarried and sawn up into slabs in the factory. The slabs are polished, some being used for decorative purposes, while other blocks of marble are used for sculpture, of which specimens are seen.

Appraisal : This film would be of more use in the teaching of economic geography than of geology, as the uses to which limestone and marble are put are illustrated in detail. No reference is made to the chemical nature of the substances. The film needs to be accompanied by a running commentary

from the teacher, pointing out, for instance, where the deposits are found, and drawing attention to the lime kilns, which are of a type unfamiliar to English children. Adequate material for this is provided in the teaching notes : without commentary or teaching notes the film would be of considerably less use, as the captions are insufficient in number, and not always well placed. The photography on the whole is good, but the film is somewhat jerky, and lacks continuity which is not supplied by the captions.

Suitability : A background film for children of 11 +, but it would be somewhat difficult to fit into the English curriculum. Might also be of interest to classes of building construction.

Sand and Clay (U.S.A.), 1934

16-mm. silent, 8-mm. silent, 400 feet, 16 minutes, 1 reel. Teaching notes available.

Distributors : Kodak, Ltd., Wealdstone, Harrow, Middlesex.

Contents : The film opens with shots of a granite cliff partly cut away for a road, showing the exposed granite. The granite is blasted, and the structure of the granite is shown by a microphotograph in which the grains of quartz, from which sand is formed, are seen. The artificial production of sandstone is followed by a view of a sandstone quarry, where the sandstone is seen cut out, after which the making of grindstones is shown. The next portion of the film shows how sand is used in the manufacture of glass, which is seen being rolled and polished. The last part of the film deals with clay, the quarrying of slate, the manufacture of bricks from clay, and the making of pottery.

Appraisal : This film attempts to cover too wide a field, and in consequence lacks coherence and leaves many gaps which would need to be filled in by the teacher. The sequences showing glass manufacture and the splitting of slates in the slate quarry afford opportunities for some rather striking shots. Like the complementary film " Limestone and Marble," it contains a great deal of material interesting from the point of view of economic geography and industry, while its actual geological value is not very great. The title of the film is a little misleading. The film would need to be accompanied by a commentary from the teacher, for which material is provided in the teaching notes ; the latter are essential to a proper understanding of the film. It might have been better to incorporate much of this material in the film, to supplement the rather inadequate captions. The section dealing with the making of pottery could have been shorter, without any loss to the educational value of the film.

Suitability : A background film for children of 11 +, which might be used at the end of term for revision ; also of general interest for school science societies.

PHYSICS

Current Electricity (U.S.A.), 1932

16-mm. silent, 350 feet, 14 minutes, 1 reel. Teaching notes not available.

Distributors : Wallace Heaton Ltd., 127 New Bond Street, London, W.1.

Contents : By means of diagrams, current electricity is compared with the flow of water through pipes. Very simple definitions are given, by this means, of electrons, difference of potential, current flow, amperes, volts and resistances.

Appraisal : As a teaching film this contains too much to be assimilated by a pupil in one lesson, but would be very useful as a revision and a survey at the end of a course in this subject.

Suitability : For children of 13 years of age and over, if modified as suggested.

The History of Electricity (Great Britain), 1932

35-mm. silent, 16-mm. silent, 1,100 feet, 17 minutes, 1 reel. Teaching notes not available.

Distributors : British Electrical Development Association, 2 Savoy Hill, London, W.C.2, and National Film Library, British Film Institute, 4 Great Russell Street, London, W C.1.

Contents : A short sketch of the discovery of electricity, followed by an account of its production at the present time. After some references to the work of Thales and Faraday, illustrated by reconstructed scenes and models of Faraday's apparatus, the film shows a modern power station. To-day, electricity has its origin in coal   A ciné-diagram illustrates the passage of the coal to the turbine furnaces ; the burnt ash is removed by suction.   The first steam turbine is then contrasted with a modern turbine. The switchboard of a modern power station is shown, and then the film describes how electricity is conveyed by land wires over the countryside.   Underground cables are seen being laid at a private house, and the film concludes by showing how the load chart rises and falls at definite periods throughout the day, and explains and shows the reasons for this variation.

Appraisal : The title of this film is definitely misleading, as it does not, in fact, give a history of electricity.   The film would have been much better divided into three portions : first, a definite history of the development of electrical engineering up to the time of modern practice, commencing from the time of Thales and linking the discovery of static electricity, magnetic phenomena, current electricity and Faraday's experiments which showed the relationship between all these forms of electrical energy.   The second two portions would then deal with the modern developments of electrical engineering proper and the generation of electrical energy by both steam and water power respectively.   The film as it stands is very disjointed and devotes the bulk of the time to the steam side and unfortunately the subject matter is taken from very old stations and gives little idea of the layout and equipment of a modern generating station

Suitability : For classes of children from the age of 12 upwards, if commented on by a technical man.

Illumination (U S A.), 1934

16-mm. silent, 8-mm. silent, 400 feet, 16 minutes, 1 reel. Teaching notes available.

Distributors : Kodak, Ltd , Wealdstone, Harrow, Middlesex.

Contents : The subject is introduced by scenes of a large building at night, showing the use of artificial light in general illumination and advertising. A historical survey of lighting follows, giving the progress from torches, the classical bronze oil lamp, firelight, candles, early oil lamps, to the early use of gas in the fishtail burner, with its development using a gas mantle, and ending with the various types of electric lamp.   The next part of the film deals with the measurement of illumination, demonstrating the use of the Lummer Brodhun photometer and the working out of the calculation to find the value of the candle power of the unknown lamp   This is followed by a demonstration of direct measurement of candle power by a foot-candle meter.   The next section shows factors affecting the quality of lighting—glare and shadows, and how these may be avoided—and the film ends with illustrations of direct and indirect sources of illumination.

Appraisal : The first part of this film is more satisfactory than the latter, and gives a useful summary of the progress of illumination through the ages. Curiously, it omits any mention of the inverted incandescent gas mantle.

Suitability : For classes aged 14 +.

16

Simple Machines (U.S.A), 1934

16-mm. silent, 8-mm. silent, 400 feet, 16 minutes, 1 reel.   Teaching notes available.

Distributors : Kodak, Ltd., Wealdstone, Harrow, Middlesex.

Contents : After an introductory scene of boys playing with a see-saw, various examples of levers are shown—a woman drawing water from a well with an old-fashioned well sweep, a crane, a workman using a crowbar, a steel-yard, a truck being weighed on a weighing platform and finally a pair of dial scales—the working of the levers being shown by animated diagrams.

Next the wheel and axle, and fixed and movable pulleys are illustrated and explained with labelled diagrams, after which follow examples of the inclined plane—a spiral stairway, the screw and the action of a wedge.   The film ends with examples of combinations of simple machines—a steam shovel used in excavating, embodying the various principles illustrated, followed by a truck ascending an inclined plane.

Appraisal : Though not wholly satisfactory, this film ' demonstrates clearly some of the principles involved in the use of the simple machines illustrated—levers, wheels and inclined planes.

The best use of the film would be as a revision lesson after a preliminary course in the subject.   The teaching notes give a fuller treatment of the subject in very good style and completeness, enhancing the educational value of the film.

Suitability : For classes aged 13–16.

NOTES AND CORRESPONDENCE

The Association of Scientific Workers—Scientific Films Committee

Abstract of Memorandum on *The Scientific Film* published by the Scientific Films Committee of the Association of Scientific Workers, 30 Bedford Row, W.C.1 (published in *Documentary News Letter*, July 1941; and reprinted in the *Journal of the Royal Photographic Society*).

The film is the most compelling medium for explaining facts and for interpreting new relationships between facts and their social context. A better understanding of the scientific facts on which modern civilization is based is necessary both for the people generally and for their governments if they are to make better use of the possibilities available to-day. Scientific films can help to satisfy the widespread desire to find sense and order in a changing world The increasing demand for seeing such films is shown by the success of various " shorts " and of the film biographies of Pasteur, Edison and Ehrlich. This demand has led to the founding of the London Scientific Film Society (1939) and of others in Glasgow and Aberdeen (1940), and scientific films have been included in the less regular shows to the Army, A R P., and other audiences, which have been stimulated and have asked for more of them.

The Scientific Films Committee of the Association of Scientific Workers, 30 Bedford Row, W.C 1, have published a memorandum on The Scientific Film, calling attention to the great value of the film in increasing the wider understanding of science ; emphasizing certain principles essential for making good scientific films ; and calling for further films to be made on the facts and principles of science, on great scientists (British as well as others), and on the relation of science to society in agriculture, health, housing, food manufacture, communications, etc. The film can not only instruct democracy, but can portray democracy and thus can act as a valuable export.

The S F.C issues a list of scientific films viewed and appraised, and will provide advice and help in arranging shows of such films.

SPECIMEN PROGRAMMES

MIXED PROGRAMMES OF GENERAL INTEREST

1. Vitamins . . . . 20 mins.	A history of the discovery of Vitamins, mainly Vitamin C (in fresh fruit and vegetables) and their effect on health.
Vital Service . . 6 ,,	The heating of a hospital theatre.
Protection of Fruit . 19 ,,	Widespread pests of apples, etc., and their control.

2. In All His Glory	11 mins.	The pollination of about 12 common flowers.
How Talkies Talk .	12 ,,	A simple explanation of the sound film.
Children at School . .	22 ,,	A survey of bad and good school buildings, and the need for a rebuilding programme.
	―	
	45	
3. We Live in Two Worlds	25 mins.	The contrast between the international nature of communications and national customs.
How the Telephone Works	5 ,,	A simple diagrammatic explanation.
Men in Danger	25 ,,	Industrial health and the protection of the workers
	―	
	55	

THEME PROGRAMMES OF GENERAL INTEREST

1. *Health*

Red Army	10 mins.	Bed bugs, their life story and their eradication
Enough to Eat ?	22 ,,	The nutrition film
Men in Danger	25 ,,	Industrial health
	―	
	57	

2. *Agriculture*

Woodwasp .	11 mins.	The danger to forests and the eradication of the woodwasp.
Mediæval Village . .	22 ,,	Study of a village where the old open-field system still works.
Speed the Plough . .	18 ,,	Mechanization in agriculture.
Protection of Fruit	19 ,,	Fruit pests and their prevention
	―	
	70	

PROGRAMMES OF INTEREST TO SCIENTIFIC AUDIENCES

1. *Science applied to industry*

Transfer of Power	18 mins	The history of the gear wheel.
Distillation .	15 ,,	Chemical and physical principles of fractional distillation applied to oil.
Hydraulics .	13 ,,	First principles, and application to cars, aeroplane control, etc.
	―	
	46	

2. *Physics*

Cathode Ray Oscillograph	25 mins.	Fundamental principles and some general uses of it.
Mouvements Vibratoire .	11 ,,	Simple harmonic motion.
How Talkies Talk . .	12 ,,	The principles of the sound film.
	―	
	48	

3. *Biology*

Development of the Chick	20 mins	The growth of the chick embryo photographed by transmitted light.
Astacus	20 ,,	Anatomy of the crayfish.
Life Cycle of a Plant .	10 ,,	Growth of lupin from seed to seed.
	50	

4. *History of Science*

Transfer of Power .	18 mins	History of the gear wheel and its interactions with the steel and oil industries.
Colloids in Medicine .	20 ,,	Discovery and investigation of properties of colloids.
Vitamins .	20 ,,	History of vitamin research and study of malnutrition.
Paraffin Young	13 ,,	Andrew Young and the shale industry.
	71	

The above are examples of the kind of programmes that can be built up using scientific films   You may require a special programme, and the Scientific Films Committee would be glad to work one out for you.

SCIENTIFIC FILMS COMMITTEE.

ASSOCIATION OF SCIENTIFIC WORKERS,
   30 BEDFORD ROW, LONDON, W.C.1.

A Dissection Hint

SIR,

I am disturbed to note the complaint of the reviewer of the film, " The Frog," in your last issue, that the ligaturing of the " ventral vessel " was neither mentioned nor demonstrated. Why should it be ? Why should so important a vessel be severed and the student left to trace the blood from the femoral vein, and the pelvic, into a miserable little tag-end tied with cotton, and waving pathetically, disconnectedly, and usually above the water in his dish ?

It frequently happens that the frog provides the young student with his first introduction to vertebrate dissection. It is, therefore, particularly distressing to think that he should be, so early, taught so slovenly a violation of the principles of good dissection as the ligaturing of the anterior abdominal vein. It is so easy to cut the ventral body wall along either side of the vessel, and across in front of the point at which it dives into the liver ; then to dissect off the covering strip of the body-wall, until the vein is cleared back to the pelvis. The strip can then be cut away, leaving the vein intact and clean —and meaning something. It is purely a matter of the correct tension on the muscle strip, and a sharp scalpel tip, plus a small degree of patience. Surely this is not asking much in the interests of technical discipline and a tidy dissection.

I am, Sir,
Yours faithfully,
   A. HARVEY.

DEPARTMENT OF ZOOLOGY,
   UNIVERSITY COLLEGE
      OF THE SOUTH-WEST OF ENGLAND,
         EXETER.

Some Suggestions

Sir,

May I express my appreciation of the recent articles in *S.S.R.* which have been in the form of " Lesson Notes." I feel that the *S S.R.* should devote more space to articles and sections which are directly connected with school science—that is, articles on methods of teaching and introducing definite topics in a Science curriculum, articles on various problems connected with laboratory planning and organization, etc. Why not symposiums to which several of our leading science teachers, of acknowledged experience, contribute their views on such specific questions as " How and at what point do you introduce the idea of valency (or potential, or a dozen other equally important topics) " ? Surely such discussions would be of tremendous help to younger science teachers, who have taught long enough to realise the art of Science *Teaching* ! I wonder how many of you teachers turn first to the " Notes " section of the *S.S.R.* rather than, say, a more theoretical topic such as " Recent Views on Resonance " or something of that kind ?

One other point ; is there any way in which a scheme could be devised whereby younger science teachers of say 6–8 years' experience might spend a week or fortnight as " observers " in the actual classes and laboratories of one of our first-rate teachers ? What keen teacher of Chemistry who is familiar with " Lecture Experiments in Chemistry " would not be eager to watch the author at his ordinary day-to-day teaching ? Would not such a period be of much greater value than attending a short course ?

Yours faithfully,
C. W. OTHEN.

RUTHIN COUNTY SCHOOL,
N. WALES.

A Numerical Sequence

Sir,

The following arithmetical progression may interest your readers. Some may be able to extend it in one or other direction.

100	B.P centigrade scale
320	10 g. F.P.S. units
540	Latent heat steam cals./gm.
760	S.P. in mms. mercury
980	g C.G S. units

Yours faithfully,
R H. SMITH.

" A Reader's Queries " (cf. H. G Andrew, *S.S R*, 1941, 23, 117)

(1) Carbon forms both anions and cations ; it is amphoteric A curious thing is that carbon anions are more stable when also joined by a triple-bond to another atom, as in the examples that follow :

acetylide ion	$\bar{C}\equiv\bar{C}$
*iso*cyanide group	$\bar{C}\equiv\overset{+}{N}-R$
carbon monoxide . . .	$\bar{C}\equiv\overset{+}{O}$
cyanide ion . . .	$\bar{C}\equiv N$

The fulminates are the most unstable compounds of this class : $R-O-\overset{+}{N}\equiv\bar{C}$.

If triphenylmethyl, $\varphi_3 C$, is dissolved in a polar solvent such as sulphur dioxide or ether, the following type of reaction occurs :

$$\varphi_3 C + Et_2 O = \varphi_3\overset{+}{C}OEt_2 + \varphi_3\bar{C}$$
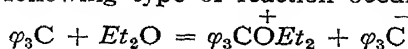
Here we have a *carbanion*, $\varphi_3 C$. Ions of this type are usually coloured. Triphenylmethyl bromide, $\varphi_3 CBr$, dissolved in liquid sulphur dioxide at $0°$ C. is a better conductor of electricity than potassium iodide in this solvent (Walden, *Ber.*, 1902, **35**, 2023).

When triphenylmethyl chloride, $\varphi_3 CCl$, and silver perchlorate are mixed in a solution of benzene and nitrobenzene, triphenylmethyl perchlorate, $\varphi_3 CClO_4$, forms in red crystals which conduct the electric current in tetrachloroethane. It is therefore the salt $\varphi_3 \overset{+}{C}\ \overset{-}{ClO_4}$ containing the red *carbonium ion*, $\varphi_3 \overset{+}{C}$.

Graphite forms salts with strong acids, e.g , graphite bisulphate. This is due to the presence of the so-called *mobile electrons* in the graphite hexagonal lattice of carbon atoms. These confer upon graphite those properties in which it resembles a metal. These mobile electrons will be available when carbon is used as an electrode, for all " amorphous " varieties of carbon are essentially graphitic (S. T. Bowden, *S.S.R.*, 1940, **21**, 1064). For details about the salt-formation of graphite see *Trans. Farad. Soc*, 1938, **34**, 1011–84.

I should say that carbon differs from a true metal *in not being able to give cations by ionization*. Copper, for example, can yield cuprous and cupric ions, and these reactions are reversible (as with all metals), so that we get the $Cu/Cu+$ and $Cu/Cu++$ reversible electrodes with their corresponding standard electrode potentials. As far as I know this is not possible with graphite, and so it would be interesting to make some experiments with graphite in a solution containing acetylide ions, although it might be difficult to find a suitable solvent.

The question raised by Mr Andrew is connected with a well-known electrode : the glass electrode discovered by the biologist Cremer in 1906. It acts as a very accurate reversible hydrogen electrode from pH 0 to 9, apparently because hydrogen ions are able to migrate through glass. Lengyel and Lark-Horovitz have replaced glass by quartz, paraffin, and Acheson graphite, and find much the same results as with glass (for graphite, see B. v. Lengyel, *Zeit phhsik Chem*, 1931, **154**, 371).

I think that Mr. Andrew will find that if carbon is regarded as a fairly good conductor of electrons it can be compared to any other " inert " electrode, such as platinum.

(2) The three reactions mentioned by Mr. Andrew are certainly of the same kind in the sense that hydrolysis of a salt leads to a volatile acid. Even assuming the acids to be equally volatile in aqueous solution, there is no reason why they should be produced in aqueous solution from salt and water *at equal rates*. The overall rate of a reaction is determined by its *slowest* stage, just as in the production of a commodity in stages the slowest stage will determine the rate of production—a well-recognized fact in economics. If the rate of the change

$$\text{salt} + \text{water} \longrightarrow \text{alkali} + \text{acid (dissolved)}$$

is slower than

$$\text{acid (dissolved)} \longrightarrow \text{acid (vapour)},$$
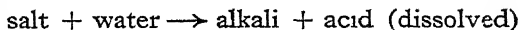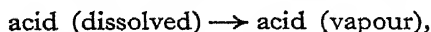
then the first reaction determines the overall rate. From this point of view it can be surmised that the rates of the reactions

$$Na_2CO_3 + H_2O \longrightarrow 2NaOH + CO_2 \text{ (dissolved)}$$

and

$$Na_2B_4O_7 + 3H_2O \longrightarrow 2NaBO_2 + 2H_3BO_3 \text{ (dissolved)}$$

are slow, whilst

$$AlCl_3 + 3H_2O \longrightarrow Al(OH)_3 + 3HCl \text{ (dissolved)}$$
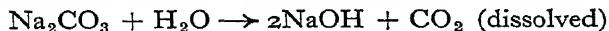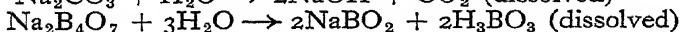
is rapid.

GEORGE NOVELLO COPLEY.

REVIEWS

Text-Book of Physical Chemistry. By SAMUEL GLASSTONE, D.Sc., Ph.D.
(London : Macmillan & Co., 1940.) Pp. xiii + 1289. Price 42s. net.

THIS important book, designed to lead the student who has followed a " very elementary " course of general chemistry to a stage at which he can profitably read advanced treatises and original literature, is claimed by its author to be the first " complete work of an intermediate character " upon Physical Chemistry to be published, " at least in the English language." In view of this, it is perhaps as well to examine, as far as space permits, the respects in which it can be said to differ from other " intermediate " works on the subject, of which there are many.

Briefly, these differences are both intensive and extensive. To take a few examples of the former · the study of spectra is carried as far as resultant quantum numbers and Russell-Saunders coupling ; statistical methods are applied to partition functions, ortho- and para-states, and entropy ; crystal analysis includes Fourier synthesis and electron-density diagrams, and an account of the Kerr constant and its relation to molecular structure is to be found as well as discussion of other physical properties more familiar to the average chemist. The book is, however, by no means confined to theoretical principles ; an immense amount of interesting detail is to be found in its pages. The considerable section on the " solid state "—to take one example only—ranges through the known structures of the more important inorganic crystals to that of wool, cellulose and rubber, and includes evidence for the existence of rotation of ions and molecules within the space-lattice.

Minor criticisms may be advanced here and there ; it might be suggested that recent efforts to attack the difficult question of transition from covalent to ionic bond type in specific linkages merited fuller treatment, or that Pauling's rules, admittedly empirical, which have been described by W. L Bragg as " the basis of the stereochemistry of minerals," deserve more than a three-line mention ; but perhaps it may be fairly countered that there are limits to what can be included in a single volume, and that the copious references which have wisely been chosen in preference to numerical problems give ample guidance to those who wish to extend their knowledge in a particular direction.

Emphasis is laid upon the historical approach, though the work of the pioneers in atomic weight determinations is not included, and the only allusion to Cannizzaro appears to be in relation to " Kopp's Law." Such matters are presumably deemed to be part of a " very elementary " course. The general atmosphere is nevertheless modern ; in the section devoted to electro-chemistry, the Debye-Huckel theory is introduced at an early stage, equilibria being dealt with in terms of activities, and simpler relationships involving concentrations treated as limiting cases of more general equations. In this, as in other chapters, Dr. Glasstone may be considered to have justified his claim to give the " modern point of view," as compared with " grafting, as has so often been done, the more recent concepts upon a background of classical ideas."

The value of this book would appear to be considerable to those working for University degrees ; regarding its position with respect to schools, the

following may be said. Its scope and treatment are too advanced for most schoolboys, though selected passages might be recommended for scholarship and post-scholarship reading. For the teacher it should prove extremely useful as a work of reference ; more, however, can be made of it than this. Within the last generation the face of chemistry has altered so profoundly that even elementary work is affected. Such changes are mirrored darkly in examination papers ; the preparation of Scheele's green and the lead-chamber process tend to give way to electronic theory and the significance of crystal structure. Failing a standing committee of moderators—an expedient of dubious possibility and uncertain wisdom—increasing demands are made upon the learning and discretion of the schoolmaster, whose time and access to original papers are alike limited. This "Text-book of Physical Chemistry," which strikes an admirable balance between fact, theory, and experimental method, should both stimulate and sustain those who are trying, within the extent of their powers, to solve the twin problems of what to teach and how to teach it.

A Short History of Science to the Nineteenth Century. By CHARLES SINGER. (Oxford : Clarendon Press (Sir Humphrey Milford), 1941.) Pp xiv + 400. Price 8s 6d. net.

BELIEF in a rational and universal scheme of cause and effect and the development of modern scientific method, are the two main themes of this " History." Attention is confined to those activities which have contributed to the main stream of Western scientific thought, and thus the book opens with the Ionian philosophers of the sixth century B C. Dr. Singer is particularly at home in his description of Greek science ; he then traces his story through practical Rome and theological Middle Ages to Galileo, Newton and the beginnings of modern science. So far (three-fifths of the book) Dr. Singer has been completely successful in his bold project of synthesizing the Natural Sciences into a coherent whole, but after this the attempt becomes more difficult and the subdivisions more obvious. Energy, Atomism, Evolution, these are the doctrines Dr. Singer traces side by side to the middle of the nineteenth century. We are left with the melancholy thought that scientific knowledge now has such detailed complexity that further synthesis of the separate branches is a task beyond the powers of any man. However, this is not the author's fault, and he has been successful within most of his time range and nearly successful throughout the whole. Nowadays, we are all technicians ; this book usefully widens the narrowing horizons of those who learn " more and more of less and less."

There may be a few errors in details (on page 315 occurs the curious suggestion that an electric motor needs to be supplied from an induction coil), but the book is interesting, readable, scholarly, non-technical and thoroughly to be recommended.

Chemical Species. By JEAN TIMMERMANS, translated by RALPH E. OESPER. (London : Macmillan & Co., 1941.) Pp. viii + 177. Price 18s. net.

PROFESSOR TIMMERMANS has been Director of the International Bureau of Physico-Chemical Standards at Brussels since its creation in 1921, and a translation of his *La Notion d'Espèce en Chemie* is particularly welcome. The book is divided into four parts which provide answers to the following questions : " I. How may a given physico-chemical system be defined without ambiguity ? This is the problem of chemical species. II How may such a system be realized ? This is the problem of pure materials. III How may its constants be measured with precision and exactitude ? IV How may the best method of purification and the most probable value of the constants of pure materials be found in the literature ? "

Apart from its value, not so much as a work of reference but as a guide to the subject, the book should be read widely by chemistry teachers, who will find here sound reasons for revising many notions, long accepted without question from text-books and often in need of fresh definition in the light of modern knowledge. The historical introductions to Parts I and II are particularly illuminating.

The translation is good and the book is very readable considering the subject. It certainly merits a place in a school science library. Some of the labelling of figures (e.g., figs. 1 and 2) and of tables (e.g., on p. 31) leaves something to be desired.

Elementary Physics and Chemistry for Students of Biology. By E. A. WOODALL, B.Sc., Ph.D., and E. C. DENNE, B.Sc. (London : George G. Harrap & Co., Ltd.) Pp. 224. Price 4s. 6d.

THIS book contains material for what the authors describe as a General Science course for pupils who are taking Biology as their main science subject. The term " General Science " is rather misleading since the course consists almost entirely of Physics. The authors recommend that the course should be given in the two years preceding the School Certificate year. While there are still many girls' schools where Biology may be the only science taught, it came as a surprise to the reviewer to learn that there are boys' schools where such conditions prevail. 175 of the 208 pages deal with physical principles and their application This section is very well done indeed ; the exposition is clear and concise and the many diagrams are excellent, and at the end of each chapter the use of the particular physical principle in Biology is discussed. By comparison, the small section dealing with the chemistry the authors consider necessary—they believe that much of the chemistry needed can be taught satisfactorily in the Biology course proper—is less satisfactory. The information is scrappy and contains some inaccurate and misleading information ; e.g , " Most metals will dissolve in acids, forming a salt with the evolution of hydrogen " (p. 200) ; " Nitrogen will combine with hydrogen if an electric charge is passed through a mixture of the two gases " (p. 206) ; " Glycerine *neutralizes* certain organic acids " (p. 216). The section dealing with hardness of water is limited to two experiments, giving the impression that washing soda removes permanent hardness only.

New Style Tests in Chemistry. By A. C. CAVELL, B.Sc., B.A. (London : Edward Arnold & Co., 1941.) Pp 48. Price 1s. 3d.

THESE tests appear to have been carefully selected to cover most of the ground to School Certificate stage. They may be answered on plain paper if it is not desired to mark the book. The reviewer thinks it an advantage to have perforated pages for those desiring them, the pagination being arranged to suit.

General Science for Colonial Schools. Book III. By F. DANIEL, B.Sc. (Oxford University Press (Sir Humphrey Milford), 1941.) Pp. x + 296. Price 3s.

THIS, the third book of the series, contains five chapters dealing with Heat, Animal Life, Other Living Things, Light, and Magnetism. The Appendices contain adequate suggestions and directions for practical work on Plants and Animals.

The same excellent planning and exposition are to be found in this as were evident in the earlier volumes. Mr. Daniel writes clearly and interestingly ; his text is very well illustrated. His knowledge of science (chemical,

physical and biological) is extensive, and he has done a great service to General Science teaching in applying it so thoroughly in the preparation of this series of books.

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Algebraic Solid Geometry. By S. L. GREEN, M.Sc. (Cambridge University Press, 1941.) Pp. 132. Price 6s. net.

The A B C of Criminology. By ANITA M. MUHL, B Sc., M.D., Ph.D. (Melbourne University Press in association with Oxford University Press, 1941.) Pp. 238. Price 8s. 6d.

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